



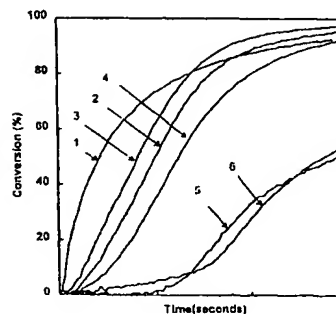
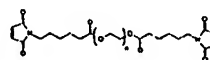
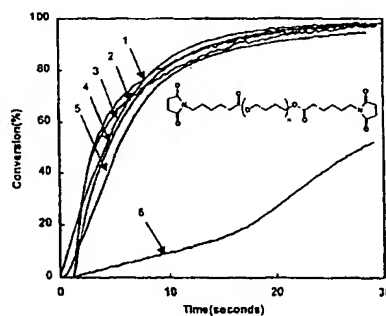
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(54) Title: WATER COMPATIBLE ENERGY CURABLE COMPOSITIONS CONTAINING MALEIMIDE DERIVATIVES

(57) Abstract

Active water compatible energy curable compositions comprised of maleimide derivatives, water compatible resins and water which are capable of curing at a practical intensity and energy level and a method for curing same.



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WATER COMPATIBLE ENERGY CURABLE COMPOSITIONS CONTAINING
MALEIMIDE DERIVATIVES

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to active water compatible energy curable compositions containing a maleimide derivative, useful for preparing various coatings, printing inks, surface finishes, moldings, laminated plates, adhesives, and binders.

10 More specifically, the present invention relates to an active water compatible energy curable compositions which can be cured in the absence of a photoinitiator with a irradiation source of practical intensity and energy value.

15 Description of Related Art

An active energy curable composition polymerized under irradiation of active energy such as thermal energy, ultraviolet light, visible light, and the like, has an advantage of being rapidly cured. Active energy curable compositions are widely
20 used as paints, inks, adhesives, coatings, and the like. However, conventional ultraviolet active energy curable compositions cannot initiate polymerization alone upon irradiation with an energy source; it is therefore necessary to use a photoinitiator. When photoinitiators are used in large
25 quantities, curing progresses rapidly which encourages the use of large quantities of photoinitiator.

Photoinitiator compounds having an aromatic ring are used in general because they effectively absorb ultraviolet light. However, these compounds cause problems such as the yellowing of
30 the cured materials upon addition of heat or light. Moreover, low molecular weight energy curable monomers and oligomers,

5 commonly used as photoinitiators because of their solubility a
property necessary to initiate photopolymerization effectively,
unfortunately have high vapor pressures. Therefore, they tend
to give off unpleasant odors at temperatures ranging from room
temperature to 150°C. Because infrared light, for example, is
10 generated from an ultraviolet energy source, active energy
curable compositions are heated substantially upon contact with
such light sources. The heating problem is magnified when the
ultraviolet light lamps are arranged and used in a side by side
fashion. The unpleasant odors given off from the photoinitiator
15 result in an unhealthy working environment.

Unreacted or decomposed photoinitiators remain behind in
conventional energy curable compositions even after exposure to
irradiation by the active energy cure source. These unreacted
or decomposed photoinitiators cause problems such as changing
20 the color of the cured film to yellow, unpleasant odors, and the
like, when the cured film is exposed to heat or light. For
example, when a material at high temperature, such as a thermal
head, contacts an active energy curable composition comprising
photoinitiator, strong unpleasant odors are given off. Finally,
25 when these cured compositions are contacted by water after
irradiation, unreacted photoinitiator is exuded; therefore
causing the active energy curable composition to be unsuitable
for food packaging applications.

In solving some of these problems, the prior art presents
30 many options. For instance, JP-A-58-89609 discloses an energy
curable resin comprising a polymer with polymerizable
unsaturated acrylic group and an organic solvent-soluble styrene
containing an acrylic thermoplastic resin that does not need a
photoinitiator.

35 WO 89/05827 teaches photopolymerizable adhesive
compositions comprising a copolymer of methacrylate monomer
and/or methyl acrylate and a photopolymerizable monomer. These
photocurable compositions, however, cannot be sufficiently

5 cross-linked by practical irradiation energy sources.

U.S. Patent 5,446,073 and *Polymer Preprints*, Vol. 37, No. 2, pp. 348-49, 1996 disclose a photopolymerizing method in which maleimide type materials are mixed with vinyl ethers and acrylates to produce a tough film. The polymerization mechanism
10 involves a charge-transfer complex which is formed by an electron acceptor and an electron donor. However, many of the maleimides are solid and are hardly dissolved in acrylates.

Polymer Letters, Vol. 6, pp. 883-88, 1968 reports that maleimide derivatives can be polymerized in the absence of
15 photoinitiators under irradiation by ultraviolet light. Japanese Patent Applications JP-A-61-250064, JP-A-62-64813, and JP-A-62-79243 teach active energy curable compositions comprising maleimide derivatives such as alkylmaleimides and arylmaleimides. However, these maleimide derivatives show low
20 photoinitiator properties, therefore making it necessary to use substantial amounts of photoinitiator in the maleimide compositions.

U.S. Patent 3,920,618 and Japanese Patent Applications JP-A-50-123138 and JP-A-51-47940 disclose photopolymerizable
25 polymers having an α -aryl substituted maleimide group at a side chain. It is well known that these pendant type maleimides can be crosslinkable by ultraviolet irradiation (i.e. 2+2 photocycloaddition reaction). U.S. Patent 4,079,041 and Europe Patent 21019 teach polymers having side chain type maleimide
30 groups with alkyl substituents. However, these pendant type maleimides cannot be used to form linear polymers by photopolymerization. Therefore, they are most commonly used to prepare negative printing plates. In addition, the photocross-linking dimerization reaction takes a rather long time (several
35 tens seconds to several minutes) even with an excess amount of irradiation energy.

Polymer Materials Science and Engineering, Vol. 72, pp. 470-72, 1995 and *Proceedings of RadTech Europe 95*, pp. 34-56,

5 1995 disclose photocurable compositions comprising maleimide derivatives as electron acceptors and vinyl ethers as electron donors. The photopolymerizable compositions 1,4-bis(vinyloxymethyl)cyclohexane and N-cyclohexylmaleimide or 4-hydroxybutyl vinyl ether and N-(hydroxyalkyl)maleimide,
10 illustrated in these documents are polymerized upon ultra violet irradiation in the absence of a photoinitiator. However, hardening of the coated films does not occur; i.e. the coated films maintain liquid states after ultraviolet irradiation.

WO 98/07759 describes energy curable compositions wherein
15 water soluble maleimides are copolymerized with acrylates in the absence of water to produce a cured film.

The polymerizing methods described above share numerous problems, which can be summarized as the need for high irradiation intensity to cure sufficiently; the maleimide
20 derivatives being solid at ambient temperature which does not suggest whether they are or can be homo-polymerized upon irradiation in the absence of a photoinitiator; difficulty in obtaining cured coatings with practical properties and given the wide range of curable composition disclosed; the need for higher
25 irradiation energy than practical for cross-linking (photodimerization). However, none of these references describe active energy curable compositions containing water or energy curable compositions that are water compatible.

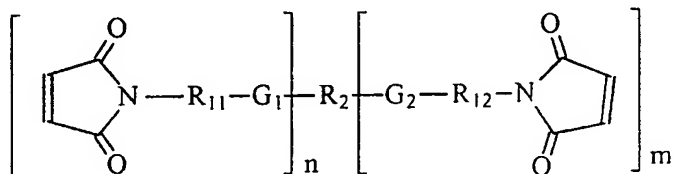
It is an object of the present invention to provide active
30 water compatible energy curable compositions which do not contain photoinitiator, cause unpleasant odors upon curing or cause yellowing, or exude materials from the cured film upon contact with water or solvent.

Another object of the present invention is to provide an
35 active water compatible energy curable composition which can be photopolymerized by an energy source of practical intensity and energy value and results in coatings that exhibit cure rates, gloss, hardness and solvent resistance values comparable to

- 5 those of conventional energy cure systems employing photoinitiators.

SUMMARY OF THE INVENTION

The present invention is an active water curable energy curable composition comprising a water compatible compound, water and a maleimide derivative represented by the Formula (1):



wherein n and m each independently represent an integer of 1 to 5, and the sum of m and n is 6 or smaller;

- 10 R_{11} and R_{12} each independently represent a linking group selected from the group consisting of a straight or branched chain alkylene group, an alicyclic group, an arylalkylene group, and a cycloalkylalkylene group. The arylalkylene group and the cycloalkyl alkylene group may have an aryl or cycloalkyl group as a main chain or a branched chain, respectively;

- 15 G_1 and G_2 each independently represent an ester linkage represented by -COO- or -OCO- and;

- 20 R_2 represents a linking chain having an average molecular weight of 100 to 100,000 selected from the group consisting of (poly)ether and (poly)ester linking chains, in which at least one group consists of a group or groups selected from a straight or branched chain alkylene group, an alkylene group having a hydroxyl group, an alicyclic group, an aryl group, and an arylalkylene group; and connected via at least one linkage
25 selected from the group consisting of an ether and an ester linkage.

5 DETAILED DESCRIPTION OF THE INVENTION

The active water curable energy curable compositions of the present invention contain a maleimide derivative of Formula 1 mentioned above. As for variables R_{11} and R_{12} of Formula 1, examples of R_{11} and R_{12} suitable for use in the present invention include straight alkylene groups such as methylene group, ethylene group, trimethylene group, tetramethylene group, pentamethylene group, hexamethylene group, heptamethylene group, octamethylene group, nonamethylene group, decamethylene group, undecamethylene group, dodecamethylene group, and the like; alkylene groups having a branched alkyl group such as 1-methylethylene group, 1-methyl-trimethylene group, 2-methyl-trimethylene group, 1-methyl-tetramethylene group, 2-methyl-tetramethylene group, 1-methyl-pentamethylene group, 2-methyl-pentamethylene group, 3-methyl-pentamethylene group, neopentyl group, and the like; alicyclic groups such as cyclopentylene group, cyclohexylene group, and the like; arylalkylene groups having an aryl group at a main chain or a side chain such as benzylene group, 2, 2-diphenyl-trimethylene group, 1-phenyl-ethylene group, 1-phenyl-tetraethylene group, 2-phenyl-tetraethylene group, and the like; cycloalkyl-alkylene group having an alicyclic group at a main chain or a side chain such as cyclohexyl-methylene group, 1-cyclohexyl-ethylene group, 1-cyclohexyl-tetraethylene group, 2-cyclohexyl-tetraethylene group, and the like. However, there are no particular limitations placed on these groups.

When the average molecular weight of R_2 as a (poly)ether or (poly)ester linking chain is less than 100, curing properties of the maleimide thereof are worse. Even if the compositions are cured, the [gel fraction] of the energy cured composition tends to be lower.

The gel fraction is the percentage of material remaining after a cured film has been refluxed, for example, in methyl ethyl ketone for 3 hours at 80°C, then dried at 100°C for one

5 hour. A cured maleimide derivative or composition which has a 99.8% gel fraction indicates that only 0.2% of the matrix was solubilized by the above reflux conditions. (i.e. a high degree of conversion).

10 The percentage conversion is defined as the ratio of functional groups to a crosslinked matrix monitored by the disappearance of an IR absorption band during the course of irradiation. This real time IR measurement allows one to quantify percent conversion and provides insight into the reactivity the composition during irradiation.

15

Brief of Description of the Drawings

Figures 1 and 2 show a plot of the percent conversion of maleimide to polymerized maleimide material over time as measured by real time infra red analysis .

20

As mentioned above, as the molecular weight of R_2 decreases, the curing properties of the maleimide became worse. Figure 1 shows a plot of real time IR data for a bismaleimide derivative (structure shown) where R_2 is polytetramethylene glycol. As the molecular weight of the repeat unit (n) decreases (i.e. 4000 (curve 1); 3000 (curve 2); 100 (curve 3); 650 (curve 4); and 250 (curve 5)) the conversion rate becomes lower. However, where the molecular weight of R_2 (curve 6) is less than 100, the real time IR data shows the rate of conversion to be sluggish. This supports employing maleimide derivatives wherein R_2 (i.e. the poly(ether), poly(ester) linking chain) is greater than 100, since a lower values yield poorer conversion rates.

30 Figure 2 shows a plot of real time IR data for a bismaleimide derivative (structure shown) where R_2 is polyethylene glycol. As the molecular weight of the repeat unit (n) decreases (i.e. 1000 (curve 1); 600 (curve 2); 400 (curve 3); 300 (curve 4)) the conversion rate becomes lower. However,

5 where the molecular weight of R_2 (curves 5 and 6) is less than 100, the real time IR data shows the rate of conversion to be sluggish.

Therefore, the results from Figures 1 and 2 suggest that the average molecular weight of R_2 be more than 100. On the
10 other hand, when the average molecular weight of R_2 is more than 100,000, such as in the case of a polyol or a polyester, the raw material for the linking chains is solid in nature and shows poor solubility in common solvents at ambient temperature. Once
15 obtained, these maleimide derivatives are virtually insoluble in common solvents, therefore, making it difficult to obtain a film and cure it. Even if a cured coating film is obtained, the surfaces of the coating shows unevenness. Therefore, it is not suitable that the average molecular weight of R_2 be more than 100,000. R_2 may also be a linkage comprising an oligomer or a
20 polymer containing the above described (poly)ether and (poly)ester groups as repeating units. Examples of R_2 suitable for use in the present invention include (poly)ether or a (poly)ester linking chains having an average molecular weight in a range of 100 to 100,000.

25 Linking chains represented by R_2 include: a (poly)ether (poly)ol residue group; a (poly)ester (poly)ol residue group; a (poly)carboxylate {(poly)ether (poly)ol} ester having a polycarboxylic acid residue group at a terminal end; a (poly)carboxylate {(poly)ester (poly)ol} ester having a
30 polycarboxylic acid residue group at a terminal end; and (poly)epoxide forming the linking chains.

Linking chains represented by a (poly)ether (poly)ol residue group have an average molecular weight of 100 to 100,000, and comprising a part in which at least one group
35 selected from the group consisting of a straight or branched chain C_2 - C_{24} alkylene group; a C_3 - C_{24} alicyclic group; and a C_6 - C_{24} aryl group, connected with an ether linking chain or a repeating unit thereof. Examples of (poly)ether (poly)ol constructing

5 linking chain include polyalkylene glycols such as polyethylene glycol, polypropylene glycol, polybutylene glycol, polytetramethylene glycol, and the like; modified alkylene glycols in which ethylene glycol, propanediol, propylene glycol, tetramethylene glycol, pentamethylene glycol, hexanediol, 10 neopentyl glycol, glycerin, trimethylolpropane, pentaerythritol, diglycerin, ditrimethylolpropane, dipentaerythritol, and the like, are modified by ethylene oxides, propylene oxides, butylene oxides, and tetrahydrofuran. Among these (poly)ether (poly)ols, modified alkylene glycols are preferable. In 15 addition, examples of (poly)ether (poly)ol constructing the above linking chain include hydrocarbon polyols such as a copolymer of ethylene oxide and propylene oxide, a copolymer of propylene glycol and tetrahydrofuran, a copolymer of ethylene glycol and tetrahydrofuran, polyisoprene glycol, hydrogenated 20 polyisoprene glycol, polybutadiene glycol, hydrogenated polybutadiene glycol, and the like; polyhydric alcohol compounds such as polytetramethylene hexaglycerin ether (modified hexaglycerin by tetrahydrofuran), and the like. However, there are no particular limitations placed on these (poly)ether 25 (poly)ols.

Linking chains represented by a (poly)ester (poly)ol residue group have an average molecular weight of 100 to 100,000, and comprising a part in which at least one group selected from the group consisting of a straight or branched 30 chain C_2-C_{24} alkylene group; a C_3-C_{24} alicyclic group; and a C_6-C_{24} aryl group; connected with an ester linking chain or a repeating unit thereof. Examples of (poly)ester (poly)ol constructing the linking chain include (poly)alkylene glycols such as polyethylene glycol, polypropylene glycol, polybutylene glycol, 35 polytetramethylene glycol, ethylene glycol, propane diol, propylene glycol, tetramethylene glycol, pentamethylene glycol, hexane diol, neopentyl glycol, glycerin, trimethylolpropane, pentaerythritol, diglycerin, ditrimethylolpropane,

5 dipentaerythritol, and the like which are modified by ϵ -caprolactone, γ -butyrolactone, δ -valerolactone, and methylvalerolactone; aliphatic polyester polyols which are synthesized by esterification of aliphatic dicarboxylic acids such as adipic acid, dimeric acid, and the like with polyols
10 such as neopentyl glycol, methylpentanediol, and the like; aromatic polyester polyols which are synthesized by esterification of aromatic dicarboxylic acids such as terephthalic acid, and the like with polyols such as neopentyl glycol, and the like; ester compounds obtained by esterification
15 of polyhydric alcohols such as polycarbonate polyol, acryl polyol, polytetramethylenehexaglyceryl ether (modified hexaglycerin by tetrahydrofuran), and the like with dicarboxylic acids such as fumaric acid, phthalic acid, isophthalic acid, itaconic acid, adipic acid, sebacic acid, maleic acid, and the
20 like; compounds having polyol group such as monoglyceride obtained by transesterification of polyhydric alcohols such as glycerin with animal and plant fatty acid esters; and the like. However, there are no particular limitations placed on these (poly)ester(poly)ols.

25 Linking chains represented by a (poly)carboxylate {(poly)ether (poly)ol} ester having a polycarboxylic acid residue group at a terminal end, obtained by esterification of (poly)ether (poly)ol with C_2 - C_6 carboxylic acid (the term of " C_2 - C_6 carboxylic" is abbreviated as a polycarboxylic acid
30 hereinafter), which have an average molecular weight of 100 to 100,000, and comprising a part in which at least one group selected from the group consisting of a straight or branched chain C_2 - C_{24} alkylene group; a C_3 - C_{24} alicyclic group; and a C_6 - C_{24} aryl group; connected with an ether linking chain or a repeating
35 unit comprising the parts. Examples of (poly)carboxylate {(poly)ether (poly)ol} ester having polycarboxylic acid at a terminal, which forms the linking chain include

5 (poly)carboxylate {(poly)ether (poly)ol} esters having
polycarboxylic acid at a terminal end which are obtained by
esterification of polycarboxylic acids such as succinic acid,
adipic acid, phthalic acid, hexahydrophthalic acid,
tetrahydrophthalic acid, fumaric acid, isophthalic acid,
10 itaconic acid, sebacic acid, maleic acid, trimellitic acid,
pyromellitic acid, benzenepentacarboxylic acid,
benzenehexacarboxylic acid, citric acid,
tetrahydrofuran tetracarboxylic acid, cyclohexanetricarboxylic
acid, and the like with (poly)ether (poly)ols disclosed in the
15 above, and the like. However, there are no particular
limitations placed on these esters.

Linking chains represented by a (poly)carboxylate
{(poly)ester (poly)ol} ester having a polycarboxylic acid
residue group at a terminal end obtained by esterification of
20 (poly)ester (poly)ol and polycarboxylic acid which have an
average molecular weight of 100 to 100,000, and comprising a
part in which at least one group selected from the group
consisting of a straight or branched chain C_2 - C_{24} alkylene group;
a C_3 - C_{24} alicyclic group; and a C_6 - C_{24} aryl group; connected with
25 an ether and an ester linking chains, or a repeating unit
comprising the parts. Examples of (poly)carboxylate
{(poly)ester (poly)ol} ester having polycarboxylic acid at a
terminal, which forms the linking chain include
(poly)carboxylate {(poly)ester (poly)ol} ester having
30 polycarboxylic acid at a terminal end which is obtained by
esterification of polycarboxylic acids such as succinic acid,
adipic acid, phthalic acid, hexahydrophthalic acid,
tetrahydrophthalic acid, fumaric acid, isophthalic acid,
itaconic acid, sebacic acid, maleic acid, trimellitic acid,
35 pyromellitic acid, benzenepentacarboxylic acid,
benzenehexacarboxylic acid, citric acid,
tetrahydrofuran tetracarboxylic acid, cyclohexanetricarboxylic
acid, and the like with (poly)ester (poly)ols disclosed in the

5 above, and the like. However, there are no particular limitations placed on these esters.

Linking chains obtained by ring-open reaction of polyepoxides having an average molecular weight of 100 to 100,000, and comprising a part in which at least one group
10 selected from the group consisting of a straight or branched chain C_2-C_{24} alkylene group; a C_3-C_{24} alicyclic group; and a C_6-C_{24} aryl group; connected with an ether linking chain, or a repeating unit comprising the parts, and the like. However, there are no particular limitations placed on these linking
15 chains. Examples of (poly)epoxide forming the linking chain include epichlorohydrin-modified bisphenol type epoxy resin synthesized by the reaction of (methyl)epichlorohydrin with bisphenol A, bisphenol F, modified ethylene oxide thereof, modified propylene oxide thereof; epichlorohydrin-modified
20 hydrogenated hydrogenated bisphenol type epoxy resin synthesized by the reaction of (methyl)epichlorohydrin with hydrogenated bisphenol A and hydrogenated bisphenol F, and by the reaction of ethylene oxide-modified or propylene oxide-modified hydrogenated bisphenol A and bisphenol F; epoxy novolak resin; compounds
25 obtained from the reaction of phenol, bisphenol, and the like with (methyl)epichlorohydrin; aromatic epoxy resin such as glycidyl ester of terephthalic acid, isophthalic acid, pyromellitic acid, and the like; polyglycidyl ethers synthesized from glycols such as (poly)ethylene glycol, (poly)propylene
30 glycol, (poly)butylene glycol, (poly)tetramethylene glycol, neopentyl glycol, and from alkylene oxide-modified glycols thereof; polyglycidyl ethers synthesized from aliphatic polyhydric alcohols such as trimethylol propane, trimethylol ethane, glycerin, diglycerin, erythritol, pentaerythritol,
35 sorbitol, 1,4-butane diol, 1,6-hexane diol, and the like, and from alkylene oxide-modified aliphatic polyhydric alcohols thereof; glycidyl esters synthesized from adipic acid, sebacic acid, maleic acid, itaconic acid, and the like; glycidyl ether

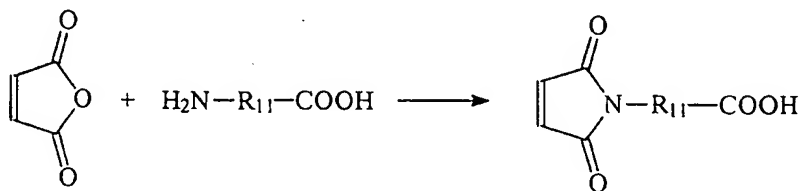
5 of polyester polyol synthesized from polyhydric alcohol with polycarboxylic acid; copolymers such as glycidyl (meth)acrylate and methylglycidyl(meth)acrylate; aliphatic epoxy resin such as glycidyl ester of higher fatty acid, epoxidized linseed oil, epoxidized soybean oil, epoxidized castor oil, epoxidized
10 polybutadiene; and the like. However, there are no particular limitations placed on these (poly)epoxides.

Among the linking chains R_2 represents, preferred are (poly)ether and (poly) ester linking chains having an average molecular weight of 100 to 100,000 and comprising a repeating
15 unit containing a C_2 - C_{24} straight chain or branched alkylene, a C_2 - C_{24} alkylene group having a hydroxyl group, and/or a C_6 - C_{24} aryl group.

The maleimide derivatives represented by Formula (1) used for an active energy curable composition of the present
20 invention can be synthesized by well known techniques from the reaction of, for example, a maleimide compound having a carboxyl group with a compound reactable with the carboxyl groups or from the reaction of a maleimide compound having a hydroxyl group with a compound having a carboxyl group.

25 A maleimide compound having a carboxyl group can be synthesized by well known techniques from the reaction of maleic anhydride with a primary amino carboxylic acid, represented by the following reaction formula. (for example, see D.H. Rich, et al., *Journal of Medical Chemistry*, Vol. 18, pp. 1004-10, 1975).

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Examples of a primary amino carboxylic acid suitable for use in such synthesis include asparagine, alanine, β -alanine, arginine, isoleucine, glycine, glutamine, tryptophan, threonine, valine, phenylalanine, homophenylalanine, α -methyl-phenylalanine, lysine, leucine, cycloleucine, 3-aminopropionic acid, α -aminobutyric acid, 4-aminobutyric acid, aminovaleric acid, 6-aminocaproic acid, 7-aminoheptanoic acid, 2-aminocaprylic acid, 3-aminocaprylic acid, 6-aminocaprylic acid, 8-aminocaprylic acid, 2-aminononanoic acid, 4-aminononanoic acid, 9-aminononanoic acid, 2-aminocapric acid, 9-aminocapric acid, 10-aminocapric acid, 2-aminoundecanoic acid, 10-aminoundecanoic acid, 11-aminoundecanoic acid, 2-aminolauric acid, 11-aminolauric acid, 12-aminolauric acid, 2-aminotridecanoic acid, 13-aminotridecanoic acid, 2-amino myristic acid, 14-amino myristic acid, 2-aminopentadecanoic acid, 15-aminopentadecanoic acid, 2-aminopalmitic acid, 16-aminopalmitic acid, 2-aminoheptadecanoic acid, 17-aminoheptadecanoic acid, 2-aminostearic acid, 18-aminostearic acid, 2-aminoeicosanoic acid, 20-aminoeicosanoic acid, aminocyclohexanecarboxylic acid, aminomethylcyclohexanecarboxylic acid, 2-amino-3-propionic acid, 3-amino-3-phenylpropionic acid, and the like. However, there are no particular limitations placed on these primary amino carboxylic acids as virtually any primary amino carboxylic acid can be used. In addition, pyrrolidone, lactams such as δ -valerolactam, ϵ -caprolactam, and the like can also be used.

Examples of compounds reactive with the carboxyl groups include polyols or polyepoxides having 2 to 6 functional groups and an average molecular weight of 100 to 100,000 comprising a part or a repeating unit in which at least one linking group selected from the group consisting of a straight chain alkylene group, a branched alkylene group, an alicyclic group, and an

5 aryl group is linked with an ether bond and/or an ester bond.

There are no particular limitations placed on the reaction between maleimide compounds having a carboxyl group and polyols one of the compound reactive with the carboxyl groups. Moreover, maleimide derivatives represented by Formula (1) can
10 be synthesized in a well-known manner disclosed in *Organic Synthesis Collective Volume* (C.E. Rehberg, et. al., Vol. 3, pp. 46, 1955). It is preferable, however, that the reaction be carried out under ambient or reduced pressure, and a temperature ranging from room temperature to 150 °C, while dehydrating and
15 using a catalyst. Examples of the catalyst include acid catalysts such as sulfuric acid, phosphoric acid, methanesulfonic acid, benzenesulfonic acid, p-toluenesulfonic acid, strong acidic cation-exchange resin, and the like. The amount of catalyst used should be within a range of 0.01 to 10
20 wt. % based on the total weight of raw materials. Moreover, an azeotropic organic solvent with water is also used as a solvent in the reaction. Examples of the azeotropic organic solvent with water include toluene, benzene, butyl acetate, ethyl acetate, diisopropyl ether, dibutyl ether, and the like.

25 There are no particular limitations placed on the reaction of the maleimide compounds having a carboxyl group with polyepoxides which are one of the reactive compound with the carboxyl groups. In addition, maleimide derivatives represented by Formula (1) can be synthesized in a well-known manner
30 disclosed in Japanese Patent Application JP-A-4-228529. It is preferable, however, that the reaction be carried out at a temperature in a range of room temperature to 150 °C, using a catalyst. Examples of the catalyst include imidazoles such as 2-methylimidazole and the like; quaternary ammonium salts such as
35 tetramethyl ammonium chloride, trimethylbenzyl ammonium chloride, tetramethyl ammonium bromide, and the like; amines such as trimethylamine, triethylamine, benzylmethylamine,

5 tributylamine, and the like; phosphines such as triphenylphosphine, tricyclohexylphosphine, and the like; laurates such as dibutyltin laurate, and the like; basic alkali metal salts such as potassium acetate, potassium tertiary phosphate, sodium acrylate, sodium methacrylate, and the like; 10 alkali alcoholates such as sodium methylate, potassium ethylate, and the like; anion-exchange resins; and the like. The amount of catalyst should be within a range of 10 to 10,000 ppm based on the total weight of raw materials.

Moreover, an organic solvent which does not comprise a 15 reactive hydrogen may also be used as a solvent in the reaction. Examples of an organic solvent which does not comprise a reactive hydrogen include aromatic hydrocarbons such as toluene, ethylbenzene, tetralin, cumene, xylene, and the like; ketones such as acetone, methyl ethyl ketone, methyl isobutyl ketone, 20 cyclohexanone, and the like; esters such as formate, methyl acetate, ethyl acetate, n-butyl acetate, and the like; and the like.

Examples of polyols used as a compound reactive with the carboxyl groups include, for example, polyalkylene glycols such 25 as polyethylene glycol, polypropylene glycol, polybutylene glycol, polytetramethylene glycol, and the like; modified alkylene glycols modified of alkylene glycols such as ethylene glycol, propanediol, propylene glycol, butanediol, butylene glycol, hexanediol, neopentyl glycol, glycerin, 30 trimethylolpropane, pentaerythritol, diglycerin, ditrimethylolpropane, dipentaerythritol, and the like by ethyleneoxide, propyleneoxide, butyleneoxide, tetrahydrofuran, ϵ -caprolactone, γ -butyrolactone, δ -valerolactone, and methylvalerolactone; aliphatic polyols such as a copolymer of 35 ethylene oxide with propylene oxide, a copolymer of propylene glycol with tetrahydrofuran, a copolymer of ethylene glycol with tetrahydrofuran, polyisoprene glycol, hydrogenated polyisoprene glycol, polybutadiene glycol, hydrogenated polybutadiene glycol,

5 and the like; aliphatic polyester polyols which are the
esterification reaction products of aliphatic dicarboxylic acids
such as adipic acid and dimeric acid with polyols such as
neopentyl glycol and methylpentanediol, and the like; aromatic
polyester polyols which are the esterification reaction products
10 of aromatic dicarboxylic acids such as terephthalate with
polyols such as neopentyl glycols; polycarbonate polyols;
acrylpolyols; polyhydric alcohols such as
polytetramethylenhexaglycerin ether (tetrahydrofuran-modified
hexaglycerin); compounds containing monohydroxyl group or
15 polyhydroxy groups, and having an ether group at terminal ends
of the polyhydric alcohols described above; compounds containing
polyhydroxyl group obtained by the esterification reaction of
the above polyhydric alcohols with dicarboxylic acids such as
fumaric acid, phthalic acid, isophthalic acid, itaconic acid,
20 adipic acid, sebacic acid, maleic acid, and the like; compounds
containing polyhydroxyl groups obtained by the
transesterification reaction of compounds containing
polyhydroxyl groups such as glycerin with ester of fatty acids
of animals and plants. Any polyols may be used if they contain
25 2 to 6 hydroxyl groups in the molecule.

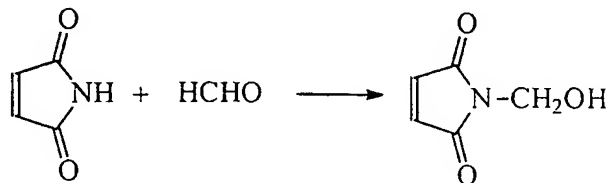
Examples of polyepoxides used as the compound reactive
with the carboxyl groups include, for example, bisphenol type
epoxy resins modified by epichlorohydrin, which are synthesized
by (methyl)epichlorohydrin with bisphenol A, and bisphenol F,
30 and their modified compounds by ethyleneoxide, propyleneoxide,
and the like; hydrogenated bisphenol type epoxy resins and epoxy
Novolak[®] resins (Novolak is a Registered Trademark of Shell
Company, Houston, TX) modified by epichlorohydrin which are
synthesized by (methyl)epichlorohydrin with hydrogenated
35 bisphenol A, hydrogenated bisphenol F, and their modified
compounds by ethyleneoxide, propyleneoxides, and the like;
reaction products of (methyl)epichlorohydrin with phenol and
biphenol; aromatic epoxy resins such as glycidyl esters of

5 terephthalic acid, isophthalic acid, and pyrrolitic acid;
polyglycidyl ethers of glycols such as (poly)ethylene glycol,
(poly)propylene glycol, (poly)butylene glycol,
(poly)tetramethylene glycol, and their alkyleneoxide-modified-
products; glycidyl ethers modified of aliphatic polyhydric
10 alcohols such as trimethylolpropane, trimethylolethane,
glycerin, diglycerin, erythritol, pentaerythritol, sorbitol, 1,
4-butanediol, 1, 6-hexanediol, and their alkyleneoxide-modified
compounds; glycidyl esters of carboxylic acids such as adipic
acid, sebacic acid, maleic acid, and itaconic acid; glycidyl
15 ethers of polyester polyols prepared by polyhydric alcohols and
polycarboxylic acids; copolymers of glycidyl(meth)acrylate and
methylglycidyl(meth)acrylate; aliphatic epoxy resins such as
glycidyl esters of higher fatty acids, epoxidized linseed oil,
epoxidized soybean oil, epoxidized castor oil, and epoxidized
20 polybutadiene.

The maleimide derivatives represented by Formula (1) used
for an active energy curable composition of the present
invention can also be synthesized by the reaction of a maleimide
compound having a hydroxyl group with a compound having a
25 carboxyl group.

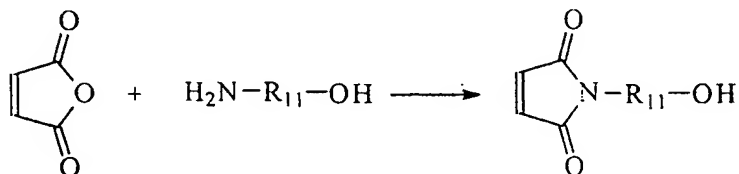
Moreover, a maleimide compound having a hydroxyl group can
be synthesized by maleimide and formaldehyde, represented by the
reaction:

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- 5 or by a well-known technique using maleic anhydride and a primary amino alcohol represented by the reaction:



(for a detailed synthesis example, see U.S. Patent No. 2526517 and Japanese Patent Application JP-A-2-268155).

- Examples of a primary amino alcohol include 2-
 10 aminoethanol, 1-amino-2-propanol, 3-amino-1-propanol, 2-amino-2-methyl-1-propanol, 2-amino-3-phenyl-1-propanol, 4-amino-1-butanol, 2-amino-1-butanol, 2-amino-3-methyl-1-butanol, 2-amino-4-methylthio-1-butanol, 2-amino-1-pentanol, 5-amino-1-pentanol,
 15 (1-aminocyclopentane)methanol, 6-amino-1-hexanol, 2-amino-1-hexanol, 7-amino-1-heptanol, 2-(2-aminoethoxy)ethanol, N-(2-aminoethyl)ethanol amine, 4-amino-1-piperazine ethanol, 2-amino-1-phenylethanol, 2-amino-3-phenyl-1-propanol, 1-aminomethyl-1-cyclohexanol, aminotrimethylcyclohexanol, and the like.

- However, there are no particular limitations placed on these
 20 primary amino alcohols. Any primary amino alcohol can be used.

- Examples of compounds reactive with the hydroxyl groups include polycarboxylic acid having ether bonds and/or ester bonds in one molecule, and an average molecular weight of 100 to 100,000, and comprising a part or a repeating unit in which at
 25 least one linking group selected from the group consisting of a straight chain alkylene group, a branched alkylene group, an alicyclic group, and an aryl group; linked with an ether bond and/or an ester bond.

- There are no particular limitations placed on the reaction
 30 between the maleimide compounds having a hydroxyl group and the

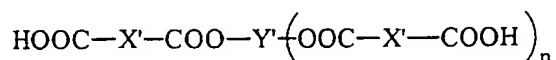
5 compounds having a carboxyl group. In addition, maleimide derivatives represented by Formula (1) can be synthesized in a well-known manner disclosed in *Organic Synthesis Collective Volume* (C.E. Rehberg, et al., Vol. 3, pp. 46, 1955). It is preferable, however, that the reaction be carried out under
10 ambient or reduced pressure, at a temperature ranging from room temperature to 150 °C, while dehydrating and using a catalyst. Examples of the catalyst include acid catalysts such as sulfuric acid, phosphoric acid, methanesulfonic acid, benzenesulfonic acid, p-toluenesulfonic acid, strong acidic cation-exchange
15 resin, and the like. The amount of catalyst should be within a range of 0.01 to 10 wt. % based on the total weight of raw materials.

In this case, as the solvent for the reaction, it is possible to use organic solvents which are azeotropic with
20 water. Examples of such organic solvents are toluene, benzene, butyl acetate, ethyl acetate, diisopropyl ether, and dibutyl ether, and the like.

In any cases of the above reactions, it is preferable to use a radical polymerization inhibitor in order to suppress the
25 radical polymerization of maleimide groups. The radical polymerization inhibitors include, for example, phenol derivatives such as hydroquinone, tert-butylhydroquinone, methoquinone, 2, 4-dimethyl-6-tert-butylphenol, catecol, tert-butylcatecol, and the like; amines such as phenothiazine, p-phenylenediamine, diphenylamine and the like; copper complexes
30 such as copper-dimethyldithiocarbamate, copper-diethyldithiocarbamate, copper-dibutyldithiocarbamate, and the like. These inhibitors may be used alone or in combinations of two or more. It is preferable to select an amount of the
35 inhibitors within a range of 10 to 10,000 ppm against total weight of raw materials.

Examples of polycarboxylic acids as the compounds, having ether bonds and ester bonds, include, for example, but are not

5 limited to, polycarboxylic acids obtained by esterification of
dicarboxylic acids such as fumaric acid, phthalic acid,
isophthalic acid, itaconic acid, adipic acid, sebacic acid,
maleic acid, succinic acid, hexahydrophthalic acid,
tetrahydrophthalic acid, pyromellitic acid, and dicarboxylic
10 acid described above with polyols described above, and
represented by formula:



wherein X' represents residual dicarboxyl groups, Y' represents residual polyol groups, and n is an integer from 1 to 5.

The maleimide derivatives represented by Formula (1) and used for the active energy curable composition of the present invention are obtained by aforementioned preparatory methods,
15 but are not limited to, the methods described herein.

It is possible to add a compound which is copolymerizable with the maleimide groups to be used together in the active energy curable composition containing maleimide derivatives according to the present invention. Practical examples of the
20 compounds which are copolymerizable with the maleimide groups are, for example, compounds having various unsaturated double bonds. Such compounds may include, for example, maleimide derivatives which are not represented by the above Formula (1), (meth)acryloyl derivatives, (meth)acrylamide derivatives, vinyl
25 ester derivatives, vinyl carboxylate derivatives, styrene derivatives, and unsaturated polyesters.

Examples of maleimide derivatives which are not represented by Formula (1) include, for example, but are not limited to:

30 monofunctional aliphatic maleimides such as N-

- 5 methylmaleimide, N-ethylmaleimide, N-propylmaleimide, N-n-butylmaleimide, N-tert-butylmaleimide, N-pentylmaleimide, N-hexylmaleimide, N-laurylmaleimide, 2-maleimideethyl-ethyl-carbonate, 2-maleimideethyl-isopropyl-carbonate, and N-ethyl-(2-maleimideethyl)carbamate; monofunctional alicyclic
- 10 maleimides such as N-cyclohexylmaleimide; aromatic monofunctional maleimides such as N-phenylmaleimide, N-2-methylphenylmaleimide, N-2-ethylphenylmaleimide, N-(2, 6-diethylphenyl)maleimide, N-2-chlorophenylmaleimide, and N-(4-hydroxyphenyl)maleimide;
- 15 aliphatic bismaleimides such as N, N'-methylenebismaleimide, N,N'-ethylenebismaleimide, N, N'-trimethylenebismaleimide, N,N'-hexamethylenebismaleimide, N, N'-dodecamethylenebismaleimide, polypropylene glycol-bis(3-maleimidepropyl) ether, tetraethylene glycol-bis(3-
- 20 maleimidepropyl) ether, and bis(2-maleimideethyl)carbonate; alicyclic bismaleimides such as 1,4-dimaleimide-cyclohexane and isophoronebisurethanebis(N-ethylmaleimide); aromatic bismaleimides such as N,N'-(4, 4'-diphenyl-methane)bismaleimide, N,N'-(4,4'-diphenyloxy)bismaleimide, N,N'-p-
- 25 phenylenebismaleimide, N, N'-m-phenylenebismaleimide, N, N'-2, 4-tolylenebismaleimide, N, N'-2,6-tolylenebis-maleimide, N, N'-[4, 4'-bis(3, 5-dimethylphenyl)methane] bismaleimide, N,N'-[4,4'-bis(3,5-diethylphenyl)methane] bismaleimide;
- (poly)urethane(poly)maleimide derivatives obtained by
- 30 urethanation reactions of hydroxymaleimides with various (poly)isocyanates, such as a maleimide derivative obtained by a urethanation reaction of hydroxyethylmaleimide with triisocyanate produced by a reaction between 3 mole of isophoronediiisocyanate and 1 mole of propyleneoxide-modified-
- 35 glycerin;
- a maleimide derivative obtained by a urethanation reaction of hydroxymethylmaleimide with diisocyanate produced by a reaction between 2 mole of 2, 4-tolylendiisocyanate and 1 mole

5 of polytetramethyleneglycol; and

compounds having acryloyloxy groups or methacryloyloxy groups can be classified into, but are not limited to, groups of (poly)ester (meth)acrylate; urethane (meth)acrylate; epoxy (meth)acrylate; (poly)ether (meth)acrylate; alkyl (meth)acrylate
10 or alkylene (meth)acrylate; (meth)acrylate having an aromatic ring and; (meth)acrylate having an alicyclic group.

Names in the above classifications are used as the general terms for respective compounds which can be used together in the active energy curable composition of the present invention. The
15 (poly)ester (meth)acrylate generally designates (meth)acrylates having at least one ester bond in the main chain; urethane (meth)acrylate generally designates (meth)acrylates having at least one urethane bond in the main chain; the epoxyacrylate generally designates (meth)acrylates obtained by a reaction
20 between (meth)acrylic acid and epoxide with one and more than one functional group; the (poly)ether (meth)acrylate generally designate (meth)acrylates having at least one ether bond in the main chain; the alkyl(meth)acrylate or alkylene(meth)acrylate generally designates
25 (meth)acrylates comprising the main chain formed by a linear alkyl, a branched alkyl, a linear alkylene, or a branched alkylene, and side chains or terminal ends having halogen atoms and/or hydroxyl groups; (meth)acrylate having an aromatic ring generally designates (meth)acrylates having an aromatic ring at
30 the main chain or the side chain; (meth)acrylate having an alicyclic group generally designates (meth)acrylates having, in the main chain or the side chain, alicyclic groups which may include oxygen atoms or nitrogen atoms as the structural unit.

Examples of the (poly)ester (meth)acrylates which can be
35 used together in the active energy curable composition of the present invention include, for example, but are not limited to, monofunctional (poly)ester(meth)acrylates such as alicyclic-modified neopentylglycol(meth)arylate, caprolactone-modified 2-

- 5 hydroxyethyl(meth)acrylate, ethyleneoxide- and/or propyleneoxide- modified phthalate(meth)acrylate, ethyleneoxide-modified succinate(meth)acrylate, caprolactone-modified tetrahydrofurfuryl(meth)acrylate; pivalate-esterneopentylglycoldi(meth)acrylate, caprolactone-modified
- 10 hydroxypivalateesterneopentylglucoldi(meth)acrylate, epichlorohydrine-modified phthalatedi(meth)acrylate; mono-, di- or tri-(meth)acrylates of triol obtained by addition of more than 1 mole of cyclic lactones such as ϵ -caprolactone, γ -butyrolactone, δ -valerolactone or methylvalerolactone to 1 mole
- 15 of trimethylolpropane or glycerin; mono-, di-, tri-, or tetra-(meth)acrylates of triol obtained by addition of more than 1 mole of cyclic lactones such as ϵ -caprolactone, γ -butyrolactone, δ -valerolactone or methylvalerolactone to 1 mole of pentaerythritol or ditrimethylolpropane; mono- or poly-
- 20 (meth)acrylates of polyhydric alcohols such as triol, tetraol, pentaol, or hexaol, obtained by addition of more than 1 mole of cyclic lactones such as ϵ -caprolactone, γ -butyrolactone, δ -valerolactone or methylvalerolactone to 1 mole of dipentaerythritol; (meth)acrylates of polyester polyols composed
- 25 of diol components such as (poly)ethylene glycol, (poly)propylene glycol, (poly)tertamethylene glycol, (poly)butylene glycol, (poly)pentanediol, (poly)methylpentanediol, and (poly)hexanediol, and polybasic acids such as maleic acid, fumaric acid, succinic acid, adipic acid, phthalic
- 30 acid, hexahydrophthalic acid, tetrahydrophthalic acid, itaconic acid, citraconic acid, hettic acid, chlorendic acid, dimeric acid, alkenylsuccinic acid, sebacic acid, azelaic acid, 2, 2, 4-trimethyladipic acid, 1, 4-cyclo-hexanedicarboxylic acid, terephthalic acid, 2-sodium-sulfoterephthalic acid, 2-potassium
- 35 sulfoterephthalic acid, isophthalic acid, 5-sodium sulfoisophthalic acid, 5-potassium sulfoisophthalic acid, orthophthalic acid, 4-sulfophthalic acid, 1, 10-

5 decamethylenedicarboxylic acid, muconic acid, oxalic acid,
malonic acid, glutaric acid, trimellitic acid, pyromellitic
acid; and polyfunctional (poly)ester (meth)acrylates composed of
the above diol components, polybasic acids, and cyclic lactone-
modified polyesterdiols such as ϵ -caprolactone, γ -butyrolactone,
10 δ -valerolactone or methylvalerolactone.

The urethane (meth)acrylate which can be used together in
the active energy curable composition of the present invention
is a general term representing (meth)acrylates obtained by a
reaction between hydroxy compounds having at least one
15 acryloyloxy group and isocyanate compounds. The urethane
(meth)acrylate may also be selected from water dilutable
aliphatic acrylate or aromatic urethanes.

Examples of hydroxy compounds having at least one
acryloyloxy group include, for example, 2-
20 hydroxyethyl(meth)acrylate, 2-hydroxypropyl(meth)acrylate, 2-
hydroxybutyl(meth)acrylate, 3-hydroxybutyl(meth)acrylate, 4-
hydroxybutyl(meth)acrylate,
cyclohexanedimethanolmono(meth)acrylate, polyethylene
glycol(meth)acrylate, polypropylene glycol(meth)acrylate,
25 trimethylolpropanedi(meth)acrylate,
trimethylolethanedimeth(meth)acrylate,
pentaerythritoltri(meth)acrylate or an adduct of (meth)acrylate
with glycidyl(meth)acrylate, (meth)acrylate compounds having
hydroxyl groups such as 2-hydroxy-3-phenolpropyl(meth)acrylate,
30 and ring-opening reaction products of the above acrylate
compounds having hydroxyl groups with ϵ -caprolactone.

Examples of isocyanate compounds include, for example,
aromatic diisocyanates such as p-phenylenediisocyanate, m-
phenylenediisocyanate, p-xylenediisocyanate, m-
35 xylenediisocyanate, 2, 4-tolylenediisocyanate, 2, 6-
tolylenediisocyanate, 4, 4'-diphenylmethanediisocyanate, 3, 3'-
dimethyldiphenyl-4, 4'-diisocyanate, 3, 3'-diethyldiphenyl-4,

- 5 4'-diisocyanate, and naphthalenediisocyanate; aliphatic or alicyclic diisocyanates such as isophoronediiisocyanate, hexamethylenediisocyanate, 4, 4'-dicyclohexylmethanediisocyanate, hydrogenated xylenediisocyanate, norbornenediisocyanate, and
- 10 lysinediisocyanate; polyisocyanates such as buret products of more than one type of isocyanates and isocyanate-trimers of the above isocyanates; and polyisocyanates obtained by the esterification reaction of the above isocyanate with various polyols.
- 15 Examples of polyols used to produce polyisocyanates include, for example, (poly)alkylene glycols such as (poly)ethylene glycol, (poly)propylene glycol, (poly)butylene glycol, and (poly)tetramethylene glycol; alkylene glycols modified by ethyleneoxide, propyleneoxide, butyleneoxide,
- 20 tetrahydrofuran, ϵ -caprolactone, γ -butyrolactone, δ -valerolactone or methylvalerolactone, such as ethylene glycol, propanediol, propylene glycol, tetramethylene glycol, pentamethylene glycol, hexanediol, neopentyl glycol, glycerin, trimethylolpropane, pentaerythritol, diglycerin,
- 25 ditrimethylolpropane, and dipentaerythritol; aliphatic polyols such as copolymers of ethyleneoxide and propyleneoxide, copolymers of propylene glycol and tetrahydrofuran, copolymers of ethylene glycol and tetrahydrofuran, polyisoprene glycol, hydrogenated polyisoprene glycol, polybutadiene glycol, and
- 30 hydrogenated polybutadiene glycol; aliphatic polyester polyols obtained by esterification reactions between aliphatic dicarboxylic acids such as adipic acid and dimeric acid with polyols such as neopentyl glycols and methylpentanediol; aromatic polyester polyols obtained by esterification reactions
- 35 between aromatic dicarboxylic acids such as terephthalic acid with polyols such as neopentyl glycol; polycarbonatepolyols; acrylpolyols; polyhydric alcohols such as polytetramethylenehexaglyceryl ether (hexaglycerin modified by

5 tetrahydrofuran); mono- or polyhydric compounds having of the
above compounds having ether group at a terminal; polyhydric
compounds obtained by esterification of the compounds having
polyhydroxyl groups with dicarboxylic acids such as fumaric
10 acid, phthalic acid, isophthalic acid, itaconic acid, adipic
acid, sebacic acid, and maleic acid; compounds containing
polyhydroxyl groups such as monoglyceride obtained by
transesterification reactions of compounds having polyhydroxyl
groups such as glycerin with esters of fatty acids of animals or
plants.

15 Epoxy(meth)acrylates capable of being used together in the
active energy curable composition of the present invention is a
general term for (meth)acrylate obtained by a reaction of
epoxides having more than one functional group and (meth)acrylic
acids. Epoxides as the raw material of epoxy(meth)acrylate
20 includes, for example, but are not limited to, epichlorohydrin-
modified-hydrogenated bisphenol-type epoxy resin, synthesized by
(methyl)epichlorohydrin and compounds such as hydrogenated
bisphenol A, hydrogenated bisphenol S, hydrogenated bisphenol F,
and their modified compounds with ethylene oxide or propylene
25 oxide; alicyclic epoxy resins such as 3, 4-
epoxycyclohexylmethyl-3, 4-epoxycyclohexane carboxy- late, bis-
(3, 4-epoxycyclohexyl) adipate; alicyclic epoxides such as epoxy
resin containing heterocycles such as triglycidylisocyanurate;
epichlorohydrine-modified bisphenol-type epoxy resins
30 synthesized by a reaction of (methyl)epi- chlorohydrin and a
compound such as bisphenol A, bisphenol S, bisphenol F, and
their modified compounds with ethylene oxide or propyleneoxide;
phenol Novolak type epoxy resins; cresol Novolak type epoxy
resins; epoxy resins of dicyclopentadiene-modified phenol resin
35 obtained by the reaction of dicyclopentadiene and various types
of phenol resins; an aromatic epoxydized compounds of 2,2',6,6'-
tetramethylbis- phenol; aromatic epoxides such as phenylglycidyl
ether; (poly)glycidyl ethers of glycol compounds such as

5 (poly)ethylene glycol, (poly)propylene glycol, (poly)butylene glycol, (poly)tetramethylene glycol, neopentyl glycol; (poly)glycidyl ether of glycols modified with alkylene oxide; (poly)glycidyl ethers of aliphatic polyhydric alcohols such as trimethylolpropane, trimethylolethane, glycerin, diglycerin, 10 erythritol, pentaerythritol, sorbitol, 1, 4-butanediol, 1, 6-hexanediol; alkylene type epoxides of (poly)glycidyl ether modified of aliphatic polyhydric alcohols by alkylene; glycidylesters of carboxylic acids such as adipic acid, sebacic acid, maleic acid, and itaconic acid; glycidyl ethers of 15 polyesterpolyols of polyhydric alcohols with polycarboxylic acids; a copolymer of glycidyl(meth)acrylate or methylglycidyl(meth)acrylate; glycidylester of higher fatty acids; aliphatic epoxy resins such as an epoxydized linseed oil, an epoxydized castor oil, and an epoxydized polybutadiene.

20 (Poly)ether (meth)acrylates capable of being used together in the active energy curable composition of the present invention include, for example, but are not limited to, aliphatic epoxy acrylates, monofunctional (poly)ether(meth)acrylates such as butoxyethyl(meth)acrylate, 25 butoxytriethylene glycol(meth)acrylate, epichlorohydrin-modified butyl(meth)acrylate, dicyclopentenylloxylethyl(meth)acrylate, 2-ethoxyethyl(meth)acrylate, ethylcarbitol(meth)acrylate, 2-methoxy(poly)ethylene glycol (meth)acrylate, methoxy(poly)propylene glycol (meth)acrylate, 30 nonylphenoxypolyethylene glycol (meth)acrylate, nonylphenoxypolypropylene glycol (meth)acrylate, phenoxyhydroxypropyl(meth)acrylate, phenoxy(poly)ethylene glycol (meth)acrylate, polyethylene glycol mono(meth)acrylate, polypropylene glycol mono(meth)acrylate, and polyethylene 35 glycol, polypropylene glycol mono(meth)acrylate; alkylene glycol di(meth)acrylates such as polyethylene glycol di(meth)acrylate, polypropylene glycol di(meth)acrylate, polybutylene glycol di(meth)acrylate, polytetramethylene glycol di(meth)acrylate;

5 polyfunctional (meth)acrylates induced by (meth)acrylic acid
with aliphatic polyols such as a copolymer of ethylene oxide and
propylene oxide, a copolymer of propylene glycol and
tetrahydrofuran, a copolymer of ethylene glycol and
tetrahydrofuran, polyisoprene glycol, hydrogenated polyisoprene
10 glycol, polybutadieneglycol, hydrogenated polybutadiene glycol;
polyfunctional (meth)acrylates induced by acrylic acid with
polyhydric alcohols such as polytetramethylenehexaglyceryl ether
(tetrahydrofuran-modified hexaglycerin); di(meth)acrylates of
diol obtained by addition of equimolar or more than 1 mole of
15 cyclic ethers such as ethylene oxide, propylene oxide, butylene
oxide and/or tetrahydrofuran to 1 mole of neopentyl oxide;
di(meth)acrylates of alkylene oxides-modified bisphenols such as
bisphenol A, bisphenol F and bisphenol S; di(meth)acrylate of
alkylene oxide-modified hydrogenated bisphenols such as
20 hydrogenated bisphenol A, hydrogenated bisphenol F, hydrogenated
bisphenol S; di(meth)acrylates of alkylene oxide-modified
trisphenols; di(meth)acrylates of alkylene oxide-modified
hydrogenated trisphenols; di(meth)acrylates of alkylene oxide-
modified p, p'-bisphenols; di(meth)acrylates of alkylene oxide-
25 modified hydrogenated bisphenols; di(meth)acrylates of alkylene
oxide-modified p, p'-dihydroxybenzophenones; mono-, di-, and
tri-(meth)acrylates of triols obtained by addition of equimolar
or more than 1 mole of ethylene oxide, propylene oxide, butylene
oxide, and/or cyclic ethers such as tetrahydrofuran to 1 mole of
30 trimethylolpropane or glycerin; mono-, di-, tri- or tetra-
(meth)acrylates obtained by addition of equimolar or more than 1
mole of ethylene oxide, propylene oxide, butylene oxide, and/or
cyclic ethers such as tetrahydrofuran to 1 mole of
pentaerythritol, ditrimethylolpropane or highly alkoxyated
35 trimethylolpropane triacrylate; monofunctional
(poly)ether(meth)acrylates or polyfunctional
(poly)ether(meth)acrylates of polyhydric alcohols such as triol,
tetraol, pentaol, or hexaol of mono- or poly-(meth)acrylates

5 obtained by addition of equimolar or more than 1 mole of ethylene oxide, propylene oxide, butylene oxide, and/or cyclic ethers such as tetrahydrofuran to 1 mole of dipentaerythritol.

Alkyl(meth)acrylates or alkylene(meth)acrylates which can be used together in the active energy curable composition of the present invention include, for example, but are not limited to, 10 monofunctional (meth)acrylates such as methyl(meth)acrylate, ethyl(meth)acrylate, propyl(meth)acrylate, isopropyl(meth)acrylate, butyl(meth)acrylate, isobutyl(meth)acrylate, pentyl(meth)acrylate, isopentyl 15 (meth)acrylate, neopentyl(meth)acrylate, hexyl(meth)acrylate, heptyl(meth)acrylate, 2-ethylhexyl(meth)acrylate, octyl(meth)acrylate, isooctyl(meth)acrylate, nonyl(meth)acrylate, decyl(meth)acrylate, dodecyl(meth)acrylate, tridecyl(meth)acrylate, pentadecyl(meth)acrylate, miristyl 20 (meth)acrylate, palmityl(meth)acrylate, stearyl(meth)acrylate, neryl(meth)acrylate, geranyl(meth)acrylate, farnecyl(meth)acrylate, hexadecyl(meth)acrylate, octadecyl(meth)acrylate, docosyl(meth)acrylate, and trans-2-hexene(meth)acrylate; di(meth)acrylates of aliphatic diols such as ethylene glycol 25 di(meth)acrylate, propylene glycol di(meth)acrylate, 1, 2-butylene glycol di(meth)acrylate, 1, 3-butylene glycol di(meth)acrylate, 1, 4-butanediol di(meth)acrylate, 1, 6-hexanediol di(meth)acrylate, neopentyl glycol di(meth)acrylate, 2-methyl-1, 8-octanediol di(meth)acrylate, 1, 9-nonanediol 30 di(meth)acrylate, and 1, 10-decanediol di(meth)acrylate; mono(meth)acrylates or poly(meth)acrylates of polyhydric alcohols such as trimethylolpropane, (hereinafter, the term "poly" is used as the general term of the poly-functionals including di, tri, tetra, and poly compounds such as 35 mono(meth)acrylate, di(meth)acrylate, and tri(meth)acrylate of trimethylolpropane), and mono(meth)acrylates or poly(meth)acrylates of polyhydric alcohols such as triol, tetraol, and hexaol, for example, glycerin, pentaerythritol, ditri-

5 methylolpropane, and dipentaerythritol; (meth)acrylates having
hydroxyl groups such as 2-hydroxyethyl(meth)acrylate, 2-
hydroxypropyl(meth)acrylate, 4-hydroxybutyl(meth)acrylate, 3-
chloro-2-hydroxyethyl(meth)acrylate; (meth)acrylates having
bromine atoms such as 2, 3-dibromopropyl(meth)acrylate,
10 tribromophenyl(meth)acrylate, ethylene oxide-modified
tribromophenyl(meth)acrylate, ethylene oxide-modified
tetrabromobisphenol A di(meth)acrylate; (meth)acrylates having
fluorine atoms such as trifluoroethyl(meth)acrylate,
pentafluoropropyl(meth)acrylate, tetrafluoropropyl(meth)
15 acrylate, octafluoropentyl(meth)acrylate, dodecafluoroheptyl
(meth)acrylate, hexadecafluorononyl(meth)acrylate,
hexafluorobutyl(meth)acrylate, 3-perfluorobutyl-2-hydroxypropyl
(meth)acrylate, 3-perfluorohexyl-2-
hydroxypropyl(meth)acrylate, 3-perfluorooctyl-2-
20 hydroxypropyl(meth)acrylate, 3-(perfluoro-5-methylhexyl)-2-
hydroxypropyl(meth)acrylate, 3-(perfluoro-7-methyloctyl)-2-
hydroxypropyl(meth)acrylate, and 3-(perfluoro-8-methyldecyl)-2-
hydroxypropyl(meth)acrylate.

(Meth)acrylates having aromatic groups which can be used
25 together in the active energy curable composition of the present
invention include, for example, but are not limited to,
monofunctional (meth)acrylates such as phenyl(meth)acrylate,
benzylacrylate; and di(meth)acrylates such as bisphenol A
diacrylate, bisphenol F diacrylate, bisphenol S diacrylate.

30 (Meth)acrylates having alicyclic groups which can be used
together in the active energy curable composition of the present
invention include, for example, but are not limited to,
monofunctional (meth)acrylates having alicyclic structures such
as cyclohexyl(meth)acrylate, cyclopentyl(meth)acrylate,
35 cycloheptyl(meth)acrylate, bicycloheptyl(meth)acrylate,
isobornyl(meth)acrylate, bicyclopentyl di(meth)acrylate,
tricyclodecyl(meth)acrylate, bicyclopentenyl(meth)acrylate,
norbornyl(meth)acrylate, bicyclooctyl(meth)acrylate,

5 tricycloheptyl(meth)acrylate, and cholesterol skeleton-
substituted (meth)acrylate; di(meth)acrylates of hydrogenated
bisphenols such as hydrogenated bisphenol A, hydrogenated
bisphenol F, hydrogenated bisphenol S, di(meth)acrylates of
hydrogenated trisphenols such as hydrogenated trisphenols, and
10 di(meth)acrylates of hydrogenated p, p'-bisphenols;
polyfunctional (meth)acrylates having cyclic structures such as
dicyclopentane type di(meth)acrylate such as "Kayarad R684"
(available from Nihon Kayaku Co., Japan), tricyclodecane
dimethyloldi(meth)acrylate, bisphenolfluorene
15 dihydroxy(meth)acrylate; and alicyclic acrylates having oxygen
atoms and/or nitrogen atoms such as tetrahydrofurfuryl
(meth)acrylate, and morpholinoethyl(meth)acrylate.

As compounds having acryloyl groups or methacryloyl groups
which can be used together in the active energy curable
20 composition of the present invention, it is possible to use,
beside the above recited compounds, for example,
poly(meth)acryl(meth)acrylates such as a reaction product of
(meth)acrylic acid polymer and glycidyl(meth)acrylate, and a
reaction product of glycidyl(meth)acrylate polymer and
25 (meth)acrylic acid; (meth)acrylate having amino groups such as
dimethylaminoethyl(meth)acrylate; isocyanul(meth)acrylates such
as tris((meth)acryloxyethyl)isocyanurate;
phosphagene(meth)acrylate such as
hexakis((meth)acryloyloxyethyl)cyclotriphosphagen];
30 (meth)acrylate having the skelton of polysiloxane;
polybutadiene(meth)acrylate; and melamine (meth)acrylate. Among
these compounds having acryloyl or methacryloyl groups, it is
preferable to use the compounds having 1 to 6 acryloyl or
methacryloyl groups.

35 (Meth)acrylamide derivatives which can be used together in
the active energy curable composition of the present invention
include, for example, monofunctional (meth)
acrylamides such as N-isopropyl(meth)acrylamide and

5 polyfunctional (meth)acrylamides such as methylenebis
(meth)acrylamide.

Compounds having vinyl ether groups which can be used together in the active energy curable composition of the present invention can be classified into, but are not limited to, the
10 following groups, in which: an alkyl vinyl ether having a terminal group substituted with at least one selected from the group consisting of a hydrogen atom, a halogen atom, a hydroxyl group, and an amino group; a cycloalkyl vinyl ether having a terminal group substituted with at least one selected from the
15 group consisting of a hydrogen atom, a halogen atom, a hydroxyl group, and an amino group; at least one vinyl ether selected from the group consisting of a monovinyl ether, a divinyl ether, and a polyvinyl ether in which a vinyl ether group is connected with alkylene group; and in which a vinyl ether group is
20 connected with at least one group with and without substituent selected from the group consisting of alkyl group, cycloalkyl group, and aromatic group, via at least one linkage selected from the group consisting of an ether linkage, an urethane linkage, and an ester linkage.

25 Alkylvinyl ethers which can be used together in the active energy curable composition includes, for example, but are not limited to, methyl vinyl ether, hydroxymethyl vinyl ether, chloromethyl vinyl ether, ethyl vinyl ether, 2-hydroxyethylvinylether, 2-chloroethylvinylether, diethyl
30 aminoethyl vinyl ether, propyl vinyl ether, 3-hydroxypropyl vinyl ether, 2-hydroxypropyl vinyl ether, 3-chloropropyl vinyl ether, 3-aminopropyl vinyl ether, isopropyl vinyl ether, butyl vinyl ether, 4-hydroxybutyl vinyl ether, isobutyl vinyl ether, 4-aminobutyl vinyl ether, pentyl vinyl ether, isopentyl vinyl
35 ether, hexyl vinyl ether, 1, 6-hexanediol monovinyl ether, heptyl vinyl ether, 2-ethylhexyl vinyl ether, octyl vinyl ether, isooctyl vinyl ether, nonyl vinyl ether, isononyl vinyl ether, decyl vinyl ether, isodecyl vinyl ether, dodecyl vinyl ether,

5 isododecyl vinyl ether, tridecyl vinyl ether, isotridecyl vinyl ether, pentadecyl vinyl ether, isopentadecyl vinyl ether, hexadecyl vinyl ether, octadecyl vinyl ether, methylene glycol divinyl ether, ethylene glycol divinyl ether, propylene glycol divinyl ether, 1, 4-butanediol divinyl ether, 1, 6-hexanediol
10 divinyl ether, cyclohexanediol divinyl ether, trimethylolpropane trivinyl ether, pentaerythritol tetravinyl ether and hexanedioic acid, bis(4-ethenyloxy)butyl] ester.

Cycloalkyl vinyl ethers which can be used together in the active energy curable composition of the present invention
15 includes, for example, but are not limited to, cyclopropyl vinyl ether, 2-hydroxycyclopropyl vinyl ether, 2-chloro-cyclopropyl vinyl ether, cyclopropylmethyl vinyl ether, cyclobutyl vinyl ether, 3-hydroxycyclobutyl vinyl ether, 3-chlorocyclobutyl vinyl ether, cyclobutylmethyl vinyl ether,
20 cyclopentyl vinyl ether, 3-hydroxycyclopentyl vinyl ether, 3-chlorocyclopentyl vinyl ether, cyclopentylmethyl vinyl ether, cyclohexyl vinyl ether, 4-hydroxycyclohexyl vinyl ether, cyclohexylmethyl vinyl ether, 4-aminocyclohexyl vinyl ether, cyclohexanediol monovinyl ether, cyclohexanedimethanol monovinyl
25 ether, and cyclohexanedimethanol divinyl ether.

Among compounds which may be used together in the active energy curable composition of the present invention including monovinyl ethers, divinyl ethers, and polyvinyl ethers, in which the vinyl ether linkage connects with an alkylene group, and at
30 least one group selected from a group consisting of a C_2 - C_{24} alkyl group, a C_2 - C_{24} alicyclic group and a C_2 - C_{24} aromatic group which may have a substituents connects with a linkage selected from a linkage consisting of an ether linkage, an urethane linkage, and an ester linkage, examples of the compounds
35 containing an ether linkage, for example, but are not limited to, ethylene glycol methyl vinyl ether, diethylene glycol monovinyl ether, diethylene glycol methylvinyl ether, diethylene glycol divinyl ether, triethylene glycol monovinyl ether,

5 triethylene glycol methylvinyl ether, triethylene glycol divinyl
ether, polyethylene glycol monovinyl ether, polyethylene glycol
methylvinyl ether, polyethylene glycol divinyl ether, propylene
glycol methylvinyl ether, dipropylene glycol monovinyl ether,
dipropylene glycol methylvinyl ether, dipropylene glycol divinyl
10 ether, tripropylene glycol monovinyl ether, tripropylene glycol
methylvinyl ether, tripropylene glycol divinyl ether,
polypropylene glycol monovinyl ether, polypropylene glycol
methylvinyl ether, polypropylene glycol divinyl ether,
tetramethylene glycol methylvinyl ether, di(tetramethylene
15 glycol) monovinyl ether, di(tetramethylene glycol)methyl vinyl
ether, di(tetramethylene glycol) divinyl ether,
tri(tetramethylene glycol) monovinyl ether, tri(tetramethylene
glycol) methylvinyl ether, tri(tetramethylene glycol) divinyl
ether, poly(tetramethylene glycol) monovinyl ether,
20 poly(tetramethylene glycol) methylvinyl ether,
poly(tetramethylene glycol) divinyl ether, 1, 6-hexanediolmethyl
vinyl ether, di(hexamethylene glycol)monovinyl ether,
di(hexamethylene glycol) methylvinyl ether, di(hexamethylene
glycol) divinyl ether, tri(hexamethylene glycol) monovinyl
25 ether, tri(hexamethylene glycol) methylvinyl ether,
tri(hexamethylene glycol) divinyl ether, poly(hexamethylene
glycol) monovinyl ether, poly(hexamethylene glycol) methylvinyl
ether, poly(hexamethylene glycol) divinyl ether.

Among compounds classified in the above having vinyl ether
30 linkages, the compounds having urethane linkages may be obtained
by the urethanating reaction between a monovinyl ether of
(poly)alkylene glycol having at least one hydroxyl group in one
molecule and a compound having at least one isocyanate group in
one molecule. Among these compounds, the monovinyl ether of
35 (poly)alkylene glycol include at least one hydroxyl group in a
molecule, for example, 2-hydroxyethyl vinyl ether, diethylene
glycol monovinyl ether, polyethylene glycol monovinyl ether, 3-
hydroxypropyl vinyl ether, 2-hydroxy-2-methylethyl vinyl ether,

5 dipropylene glycol monovinyl ether, polypropylene glycol monovinyl ether, 4-hydroxybutyl vinyl ether, and 1, 6-hexanediol monovinyl ether.

On the other hand, compounds having at least one isocyanate group in one molecule include, for example, aromatic
10 diisocyanates such as m-isopropenyl- α , α -dimethylbenzylisocyanate, p-phenylenediisocyanate, m-phenylenediisocyanate, p-xylenediisocyanate, m-xylenediisocyanate, 2, 4-tolylenediisocyanate, 2, 6-tolylenediisocyanate, 4, 4'-diphenylmethanediisocyanate, 3, 3'-
15 diethyldiphenyl-4, 4'-diisocyanate, 3, 3'-dimethyldiphenyl-4, 4'-diisocyanate, naphthalenediisocyanate; and aliphatic and alicyclic isocyanates such as propylisocyanate, isophoronediiisocyanate, hexamethylenediisocyanate, 4, 4'-dicyclohexylmethanediisocyanate, hydrogenated xylenedi-
20 isocyanate, norbornenediisocyanate, lysindiisocyanate..

It is also possible to use isocyanate compounds such as dimers or trimers comprising more than one of these isocyanate monomers, and to use adduct compounds obtained by urethanating reactions between isocyanate compounds containing more than 2
25 isocyanate groups in one molecule and various alcohols.

Various alcohols can be used for obtaining adduct products, if the alcohol contains at least one hydroxyl group. Although there is no limitation, it is preferable to use an alcohol with an average molecular weight of less than 100,000.
30 Examples of such alcohols include, for example, methanol, ethanol, propanol, isopropanol, butanol, isobutanol, ethylene glycol, 1, 3-propylene glycol, 1, 2-propylene glycol, diethylene glycol, dipropylene glycol, neopentyl glycol, 1, 3-butanediol, 1, 4-butanediol, 1, 6-hexanediol, 1, 9-nonanediol, 1, 10-decanediol, 2, 2', 4-trimethyl-1, 3-pentanediol, 3-methyl-1, 5-pentanediol, dichloroneopentyl glycol, dibromoneopentyl glycol, neopentylglycol hydroxypivalate, cyclohexanedimethylol, 1, 4-cyclohexanediol, spiro glycol, tricyclodecanedimethylol,

5 hydrogenated bisphenol A, ethylene oxide-modified bisphenol A, propylene oxide-modified bisphenol A, dimethylol propionic acid, dimethylol butanoic acid, trimethylol ethane, trimethylolpropane, glycerin, 3-methyl-pentane-1, 3, 5-triol, tris(2-hydroxyethyl)isocyanurate. Polyester-polyols, polyether-
10 polyols, polycarbonate-polyols may be used for obtaining adduct products. These alcohols can be used alone or in combinations of two or more.

Polyester-polyols obtained by reactions of the above polyol components and carboxylic acids may be used in preparing
15 the adduct products. In regard to carboxylic acids, any conventional carboxylic acids or anhydrides thereof may be used. Examples of these carboxylic acids include, for example, maleic acid, fumaric acid, itaconic acid, citraconic acid, tetrahydrophthalic acid, hettic acid, chrolendick acid, dimeric
20 acid, adipic acid, succinic acid, alkenylsuccinic acid, sebacic acid, azelaic acid, 2, 2, 4-trimethyladipic acid, 1, 4-cyclohexanedicarboxylic acid, terephthalic acid, 2-sodiumsulfoterephthalic acid, 2-potassiumsulfoterephthalic acid, isophthalic acid; 5-sodiumsulfoisophthalic acid, 5-
25 potassiumsulfoisophthalic acid; di-lower-alkylesters of 5-sodium-sulfoisophthalic acid such as dimethyl- or diethylesters of 5-sodium-sulfoisophthalic acid; orthophthalic acid, 4-sulfophthalic acid, 1, 10-decamethylenecarboxylic acid, muconic acid, oxalic acid, malonic acid, glutaric acid, trimellitic
30 acid, hexahydrophthalic acid, tetrabromophthalic acid, methylcyclohexenetricarboxylic acid or pyromellitic acid, anhydrides thereof and ester compounds of these acids with alcohols such as methanol and ethanol. It is also possible to use lactone-polyols obtained by the ring-opening reaction
35 between ϵ -caprolactam and the above described polyols.

In regard to polyether polyols, conventional polyether polyols can be used in obtaining adduct products. Examples of such polyether-polyols are, for example, but are not limited to,

5 ether glycols such as polytetramethylene glycol, propylene
oxide-modified polytetramethylene glycol, ethylene oxide-
modified polytetramethylene glycol, polypropylene glycol,
polyethylene glycol, and polyether polyols obtained by ring-
opening reactions of cyclic ethers by use of more than three
10 functional polyols as an initiator.

Polycarbonate polyols used in adduct products are obtained
by the transesterification reactions of carbonates and various
polyols. Examples of carbonates are, for example, but are not
limited to, diphenylcarbonate, bischlorophenylcarbonate,
15 dinaphtylcarbonate, phenyl-tolyl-carbonate, phenyl-chlorophenyl-
carbonate, and 2-tolyl-4-tolyl-carbonate; diaryl- or dialkyl-
carbonates such as dimethylcarbonate and diethylcarbonate.
Examples of polyols which can be used in the above reaction
include the alcohols, polyols, polyester polyols, and polyether
20 polyols described above.

Compounds having ester linkages classified in vinyl ether
groups can be obtained by the esterification reaction of
monovinyl ether of alkylene glycol having at least one hydroxyl
group in a molecule with a compound having at least one
25 carboxyl group in a molecule.

Examples of monovinyl ether of alkylene glycol having at
least one hydroxyl group in a molecule are the same compounds as
recited as components of the above compounds having urethane
bonds.

30 It is possible to use well-known carboxylic acids and
anhydride thereof for the compounds having at least one carboxyl
group in a molecule. Examples of the compound having at least
one carboxyl group in a molecule include, for example, but are
not limited to, formic acid, acetic acid, propionic acid, valeic
35 acid, benzoic acid, maleic acid, fumaric acid, itaconic acid,
citraconic acid, tetrahydrophthalic acid, hettic acid,
chlorendic acid, dimeric acid, adipic acid, succinic acid,
alkenylsuccinic acid, sebacic acid, azelaic acid, 2, 2', 4-

5 trimethyladipic acid, 1, 4-cyclohexanedicarboxyl acid,
terephthalic acid, 2-sodiumsulfoterephthalic acid, 2-
potassiumsulfoterephthalic acid, isophthalic acid, 5-sodium-
sulfoisophthalic acid, 5-potassiumsulfoisophthalic acid; di-
lower-alkylesters of 5-sodium-sulfoisophthalic acid such as
10 dimethyl- or diethyl-esters of 5-sodium-sulfoisophthalic acid,
orthophthalic acid, 4-sulfophthalic acid, 1, 10-
decamethylenedicarboxylic acid, muconic acid, oxalic acid,
malonic acid, glutaric acid, trimellitic acid, hexahydrophthalic
acid, tetrabromophthalic acid, methylcyclohexenetetracarboxylic
15 acid or pyromellitic acid, and anhydrides of these compounds.
In addition, carboxyl acids obtained by reactions between
compounds having more than two carboxylic groups and various
alcohols, which are used as a component among compounds having
urethane linkages, and which is used in obtaining adduct
20 products of isocyanate.

Vinyl carboxylate derivatives which can be used together
in the active energy curable compositions include, for example,
vinyl acetate and vinyl cinnamate. Styrene derivatives include,
for example, styrene and divinylstyrene.

25 Unsaturated polyesters which can be used together in the
active energy curable composition include, for example, maleates
such as dimethylmaleate and diethylmaleate; fumarates such as
dimethylfumarate and diethylfumarate; and esterification
products of unsaturated polycarboxylic acids such as maleic acid
30 and fumaric acid and polyhydric alcohols.

Unlimited combinations of one or more of any compounds can
be used, without being limited to the compounds described
hereinbefore and those represented by general Formula (1) as
curable compounds which can be used together in the active
35 energy curable composition of the present invention. However,
the compounds must be copolymerizable with the maleimide
derivatives described herein.

The phrase "water compatible" is used herein to describe

5 compounds that are partially or substantially water dilutable,
water soluble and/or capable of forming a water emulsion or
dispersion with the energy curable compositions herein.
However, in the case where the energy curable compositions are
used to formulate coatings, it is preferred that the particular
10 water compatible compound be compatible with both the water and
maleimide derivatives in order to avoid any phase separation or
precipitation of one or more of the components. While not
wishing to be bound by theory, the water compatible resin
compounds used for coating applications work best if they possess
15 functional groups which are compatible with water on one hand
and functional groups which are compatible with the maleimide
derivatives on the other.

Although there is no particular limitation in the ratio of
maleimide derivatives represented by Formula (1) to those
20 maleimide derivatives when both maleimide derivatives are used
together in the active energy curable composition containing
maleimide derivatives, it is preferable to select the ratio of
maleimide derivative other than those represented by Formula (1)
equal or less than 95% by weight and more preferably equal or
25 less than 90% by weight.

Although there is no limitation in the ratio of a compound
having acryloyloxy or methacryloyloxy groups to the maleimide
derivatives represented by Formula (1), when used in the active
energy curable composition of the present invention containing
30 maleimide derivatives, it is preferable to use the compound
having acryloyloxy or methacryloyloxy groups such that 100 parts
by weight of the compounds having acryloyloxy or methacryloyloxy
groups constitutes a ratio of equal or more than 5 parts by
weight of maleimide derivatives represented by Formula (1), and,
35 more preferably, the ratio of equal or more than 20 parts by
weight from the point of view of the curing speed.

When a compound having vinyl ether groups is used together
in the active energy curable composition containing maleimide

5 derivatives of the present invention, there is no limitation on the ratio to be incorporated in the composition. However, it is preferable to use the compound having vinyl ether groups such that 100 parts by weight of the compound having vinyl ether groups constitutes a ratio of equal or more than 5 parts by
10 weight of maleimide derivatives represented by Formula (1), and the use of equimolar amount of a vinyl ether group to a maleimide group is more preferable from points of view of the curing speed and a cured film property.

The active energy curable compositions of the present
15 invention have an intrinsic spectral sensitivity ranging from 200 to 400 nm, and it is possible to polymerize same under a irradiation of ultraviolet or visible light within a range of 180 to 500 nm, even without use of a photoinitiator. It was observed that lights having wavelengths at 254 nm, 308 nm, 313
20 nm, and 365 nm are effective in curing of the active energy curable composition of the present invention. It is also possible to cure or polymerize the present active energy curable composition by light other than the ultraviolet light and by heat. In addition, it is possible to cure the present active
25 energy curable composition in air and/or an inert gas. Various energy cure sources such as thermal, ultraviolet light, infrared and visible light may be used, for example, a low-pressure-mercury lamp, a high-pressure-mercury-lamp, an ultrahigh-pressure-mercury lamp, a metal halide lamp, a chemical lamp, a
30 black-light lamp, a mercury-xenon lamp, an excimer lamp, a short-arc lamp, a helium-cadmium laser, an argon laser, an excimer laser, and sunlight.

Although the active energy curable compositions of the present invention can be cured under irradiation of ultraviolet
35 light or visible light, in the absence of a photoinitiator, conventional photoinitiators may nonetheless be used for polymerization. The photoinitiators may be classified into two groups; one is an intramolecular-bond-cleavage type and the

5 other is an intramolecular-hydrogen-abstraction type.

Examples of the intramolecular-bond-cleavage type photoinitiators include, for example, acetophenones such as diethoxyacetophenone, 2-hydroxy-2-methyl-1-phenylpropane-1-one, benzyl dimethyl ketal, 1-(4-isopropylphenyl)-2-hydroxy-2-methylpropan-1-one, 4-(2-hydroxyethoxy)phenyl-(2-hydroxy-2-methylpropyl)ketone, 4-(2-hydroxyethoxy)phenyl-(2-hydroxy-2-propyl)ketone, 1-hydroxycyclohexyl-phenylketone, 2-methyl-2-morpholino(4-thiomethylphenyl)propan-1-one, and 2-benzyl-2-dimethylamino-1-(4-morpholinophenyl)-butanone; benzoin such as benzoin, benzoinmethyl ether, benzoinisopropyl ether; acylphosphine oxides such as 2, 4, 6-trimethylbenzoin diphenylphosphine oxides; benzyl and methylphenyl-glyoxyester.

Examples of intramolecular-hydrogen-abstraction type photoinitiators include, for example, benzophenones such as benzophenone, methyl-4-phenylbenzophenone o-benzoylbenzoate, 4, 4'-dichlorobenzophenone, hydroxybenzophenone, 4-benzoyl-4'-methyl-diphenylsulfide, acrylic-benzophenone, 3, 3', 4, 4'-tetra(t-butylperoxycarbonyl)benzophenone, 3, 3'-dimethyl-4-methoxybenzophenone; thioxanthenes such as 2-isopropylthioxanthone, 2, 4-dimethylthioxanthone, 2, 4-diethylthioxanthone, 2, 4-dichlorothioxanthone; aminobenzophenones such as Michler's ketone, 4, 4'-diethylaminobenzophenone; 10-butyl-2-chloroacridone, 2-ethylanthraquinone, 9, 10-phenanthrenequinone, and camphorquinone.

30 It is preferable to add the photoinitiator to the active energy curable composition within a range of 0.01 to 10.00% by weight.

Although the active energy curable compositions of the present invention can be cured by irradiation of ultraviolet, it is also possible to use a sensitizer for efficient curing.

35 Examples of such sensitizers are, for example, amines such as triethanolamine, methyldiethanolamine, triisopropanolamine, methyl 4-dimethylaminobenzoate, ethyl 4-dimethylaminobenzoate,

5 isoamyl 4-dimethylaminobenzoate, (2-dimethyl-amino)ethyl
benzoate, (n-butoxy)ethyl 4-dimethylaminobenzoate, and 2-
ethylhexyl 4-dimethylaminobenzoate. It is preferable to add the
sensitizer to the active energy curable composition within a
range of 0.01 to 10.00% by weight.

10 It is possible to further use together, if
necessary, additives such as non-reactive-compounds, inorganic
fillers, organic fillers, coupling reagents, adhesive reagents,
antifoaming reagents, leveling reagents, plasticizers,
antioxidants, ultraviolet-absorbers, flame retardants, pigments,
15 dyes, and paints.

Examples of the non-reactive compounds which are usable
together in the active energy curable composition include, for
example, but are not limited to, liquid or solid oligomers or
resins with a low reactivity or non- reactivities such as, alkyl
20 (meth)acrylate copolymer, epoxy resins, liquid polybutadiene,
liquid polybutadiene derivatives, liquid chloroprene, liquid
polypentadiene, dichloropentadiene derivative, saturated
polyester oligomer, polyether oligomer, acrylic oligomer, liquid
polyamide, polyisocyanate oligomer, xylene resin, acrylic resin,
25 ketone resin, petroleum resin, rosin resin, fluorinate-type
oligomer, silicone-type oligomer, polysulfide oligomers.

Inorganic and organic fillers are generally used for
improving mechanical properties such as strength, cushioning and
slipping properties.

30 Any conventional fillers may be used if the fillers are
compatible with the water containing composition and do not harm
the characteristics of the resin including curing. Inorganic
fillers which may be used include, for example, but are not
limited to, silicon dioxide, silicon oxide, calcium carbonate,
35 calcium silicate, magnesium carbonate, magnesium oxide, talc,
kaoline clay, calcined clay, zinc oxide, zinc sulfate, aluminum
hydroxide, aluminum oxide, glass, mica, barium sulfate, alumina
white, zeolite, silica spherules, and glass spherules. It is

5 possible to add halogen groups, epoxy groups, hydroxyl groups,
and thiol groups to these fillers by addition or by the reaction
with various coupling reagents such as a silane coupling
reagent, a titanate-type coupling reagent, an aluminum-type
coupling reagent, a zirconate-type coupling reagent, and the
10 like.

Conventional organic fillers which may be used include,
for example, but are not limited to, a benzoguanamine resin, a
silicone resin, a low-density polyethylene, a high-density
polyethylene, a polyolefin resin, ethylene-acrylate copolymer,
15 polystyrene, cross-linking polystyrene, polydivinylbenzene,
styrene-divinylbenzene copolymer, acrylic copolymer, cross-
linking acrylic resin, polymethylmethacrylate resin, vinylidene-
chloride resin, fluororesin, nylon 12, nylon 11, nylon 6/66,
phenolic resin, epoxy resin, urethane resin, and polyimide
20 resin. It is possible to add halogen groups, epoxy groups,
hydroxyl groups, and thiol groups to these organic fillers.

Examples of coupling reagents which can be used together
in the active energy curable composition of the present
invention include, for example, but are not limited to, silane
25 coupling reagents such as γ -glycidoxypyrpyltrimethoxysilane, and
 γ -chloropropyltrimethoxysilane; titanate coupling reagents such
as tetra(2, 2-diaryloxymethyl-1-butyl)bis(ditridecyl)
phosphitetitanate, and bis(dioctylpyrophosphate)
ethylenetitanate; aluminum coupling reagents such as
30 acetoalkoxyaluminumdiiisopropylate; zirconium coupling agents
such as acetylacetone-zirconium complex and the like.

Regarding additives such as adhesive reagents,
antifoaming reagents, leveling reagents, flow reagents,
plasticizers, antioxidants, ultraviolet-absorbers, flame
35 retardants, pigments, dyes, and paints, any corresponding
conventional additives may be used together, without any
limitation, in the active energy curable composition of the

5 present invention, if the additives are compatible with the water containing composition and do not harm the characteristics of the resin including the curing property.

In order to obtain the active energy curable composition of the present invention, the aforementioned components may be
10 mixed, the mixing order or mixing method are not limited.

It is substantially not necessary to use a solvent in the active energy curable composition of the present invention. However, for diluting the active energy curable composition of the present invention, it may possible to use conventional and
15 generally known solvents including ketones such as methylethylketone and methylisobutylketone; acetates such as ethyl acetate and butyl acetate; aromatic hydrocarbons such as benzene, toluene, and xylene; and alcohols such as methanol, ethanol, isopropyl alcohol, butanol; and water.

20 The active energy curable composition of the present invention is advantageously applicable for surface finishing, binders, plastic materials, molding materials, laminate plates, adhesives, bonding materials, and ink; coating materials for metals such as aluminum, iron, and copper; coating materials for
25 plastics such as vinyl chloride, acryls, polycarbonate, polyethyleneterephthalate, and a acrylonitrilbutadienestyrene copolymer, polyethylene, and polypropylene; coating materials for ceramics such as glass; coating materials for other materials such as wood, paper, printing papers, and fibers.

30 The active energy curable composition of the present invention forms a cured film without a photoinitiator under irradiation of light. Since this active energy curable composition of the present invention does not generate odor during curing, and the cured film of this composition does not
35 incur yellowing and odor, and an amount of elution from this cured film is quite low, the present composition can be advantageously applied to a field of inks such as lithographic ink, flexo-ink, gravure ink, and screen ink, and to fields of

5 gloss varnish, paper coating, wood painting, beverage can
coating, printing, soft package coating, adhesives for printed
papers and laminates, lavel coating, printing ink or adhesives,
thermosensible paper, printing ink or coating for thermosensible
paper, food package coating, printing ink, adhesives, and
10 binders, which are directly contacted with a consumer.

The following examples illustrates specific aspects of the
present invention and are nor intended to limit the scope
thereof in any respect and should not be so construed. In the
examples, all parts are by weight unless otherwise indicated.
15 The relationship of parts by weight to parts by volume is as
that of kilograms to liters.

In the examples, the energy curable compositions were
coated on opacity charts (uncoated Leneta N2A, available from
Leneta Corporation, Mawah, NJ) using a #3 Mayer rod having a
20 thickness of 7.5 microns. The ultraviolet radiation energy cure
source was provided using a conveyor type unit with a medium
pressure mercury lamp of variable light intensities (e.g. 120,
200, 300 watts per inch (wpi) available from Fusion Aetek,
Rockville, MD) at conveyor speeds varying from 100 to 200 feet
25 per minute (fpm). At 200 wpi and 100 fpm the ultraviolet
exposure dose was 228 mJ/cm², measured using a radiometer (UV
Power Puck®, Power Puck is Registered Trademark of EIT
Incorporated, VA). This dose is normally sufficient to produce
a commercially viable film. The surface hardness of the coating
30 was empirically measured by scratching the surface with a human
nail. The reflective gloss of the cured film was measured at
60° using a glossmeter (Micro-Gloss 60, available from BYK-
Gardner Incorporated, MD). The solvent resistance of the cured
film was measured by the surface with a cotton tipped applicator
35 soaked in methyl ethyl ketone (MEK), isopropyl alcohol or water
until the substrate was exposed. The number of rubs, i.e. one
stroke back and forth across a surface, were recorded. A
coating exhibiting 10 rub MEK resistance, for example, was

5 considered to be commercially feasible.

Example 1

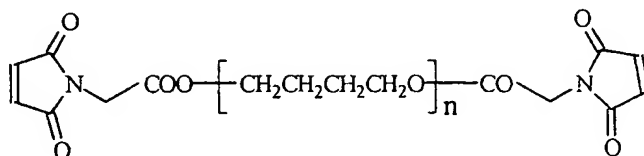
Synthesis Example

10 Glycine (37.5 g) and acetic acid (400 ml) were admixed
then a solution of maleic anhydride (49.0 g) and acetic acid
(300 ml) was added dropwise over 2 hours under stirring. The
reaction was continued for 1 hour and the precipitate that
formed was filtered off and recrystallized from a 70% aqueous
15 methanol solution. To this product (102 g), triethylamine (40.4
g), and toluene (500 ml) were added and the mixture was reacted
for 1 hour while stirring under reflux to remove the evolved
water. The residue, obtained by removing toluene from the
reaction mixture, was acidified to a pH of 2 with 0.1 N HCl,
20 extracted 3 times with ethyl acetate (100 ml) and dried with
magnesium sulfate. The ethyl acetate was then evaporated under
reduced pressure and the residue was recrystallized from water,
whereby pale yellow crystals of maleimidoacetic acid (11 g)
were obtained. ¹H NMR (300 MHz, DMSO-d₆): 7.0 ppm (s, 2H, -C=C-);
25 4.1 ppm (s, 2H, -CH₂-); IR: 3170 cm⁻¹ (-COOH); 1750 cm⁻¹; 1719
cm⁻¹ (C=O); 831 cm⁻¹; 696 cm⁻¹ (-C=C-); Elemental analysis
(CHN): Calcd. C:46.5%; H:3.87%; N:9.03%; Found C:46.2%;
H:4.05%; and N:8.70%.

30 Maleimidoacetic acid (6.8 g), polytetramethylene glycol
(10 g, MW of 250, tradename PolyTHF 250, available from BASF
Corporation, Japan), p-toluenesulfonic acid (1.2 g), 2, 6-
tert-butyl-p-cresol (0.06 g), and toluene (15 ml) were added
together and reacted at 80 °C for 4 hours under reduced pressure
35 (240 torr). The mixture was stirred and the water formed during
the reaction was removed. The reaction mixture was then
dissolved in toluene (200 ml) and washed 3 times with a

5 saturated sodium hydrogen carbonate aqueous solution (100 ml) and a saturated sodium chloride aqueous solution (100 ml). The toluene was then removed under reduced pressure and a maleimide derivative (16 g) having the structure below was obtained.

10



15

Example 2

Synthesis Example

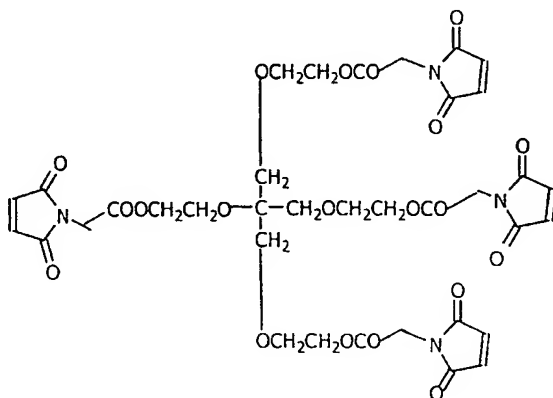
Glycine (37.5 g) and acetic acid (400 ml) were admixed
20 then a solution of maleic anhydride (49.0 g) and acetic acid (300 ml) was added dropwise over 2 hours under stirring. The reaction was continued for 1 hour and the precipitate that formed was filtered off and recrystallized from a 70% aqueous methanol solution. To this product (102 g), triethylamine (40.4
25 g) , and toluene (500 ml) were added and the mixture was reacted for 1 hour while stirring under reflux to remove the evolved water. The residue, obtained by removing toluene from the reaction mixture, was acidified to a pH of 2 with 0.1 N HCl, extracted 3 times with ethyl acetate (100 ml) and dried with
30 magnesium sulfate. The ethyl acetate was then evaporated under reduced pressure and the residue was recrystallized from water, whereby pale yellow crystals of maleimidoacetic acid (11 g) were obtained. ¹H NMR (300 MHz, DMSO-d₆): 7.0 ppm (s, 2H, -C=C-); 4.1 ppm (s, 2H, -CH₂-) IR: 3170 cm⁻¹ (-COOH); 1750 cm⁻¹; 1719 cm⁻¹ (C=O); 831 cm⁻¹; 696 cm⁻¹ (-C=C-); Elemental analysis (CHN): Calcd. C:46.5%; H:3.87%; N:9.03%; Found C:46.2%; H:4.05%; and N:8.70%.

5

Maleimidoacetic acid (6.8 g), pentaerythritol modified by 4 moles of ethylene oxide (4.1 g, tradename PNT-40 Mn:490, Mw:530, available from Nippon Emulsifying Agent Co., Ltd., Japan), p-toluenesulfonic acid (1.2 g), 2, 6-tert-butyl-p-cresol (0.06 g), and toluene (15 ml) were added together and reacted at 80 °C for 4 hours under reduced pressure (240 torr). The mixture was stirred and the water formed during the reaction was removed. The reaction mixture was then dissolved in toluene (200 ml) and washed 3 times with a saturated sodium hydrogen carbonate aqueous solution (100 ml) and a saturated sodium chloride aqueous solution (100 ml). The toluene was then removed under reduced pressure and a maleimide derivative (18 g) having the structure below was obtained.

20

25



30

Example 3

An aliphatic epoxy acrylate resin (55 wt.%, Laromer 8765, available from BASF, Mt. Olive, NJ) was combined with water (9 wt.%). Next, a maleimide as prepared in Example 1 (36 wt. %, MIA250, available from DaiNippon Ink and Chemical Corporation, Tokyo, Japan) was added. A polyether siloxane additive (0.5 wt. %, Glide 440, available from Tego Chemie, VA) was then added to produce sufficient flow properties. The curing, solvent

5 resistance, gloss and surface hardness properties of the coating
as described above were then evaluated. The results are shown
in Table 1.

Example 4

10 (Comparative)

The maleimide prepared in Example 1 (36 wt. %, MIA250,
available from DaiNippon Ink and Chemical Corporation, Tokyo,
Japan) was to water (15 wt.%). A polyether siloxane additive
(0.5 wt. %, Glide 440, available from Tego Chemie, VA) was then
15 added to produce sufficient flow properties. The energy curing
properties of the coating could not be evaluated because the
water and maleimide were found to be incompatible and no film
was produced.

20 Example 5

An aliphatic epoxy acrylate resin (58 wt.%, Laromer 8765,
available from BASF, Mt. Olive, NJ) was combined with water
(13.6 wt.%). Next, a photoinitiator, 4-(2-
25 hydroxylethoxy)phenyl-(2-hydroxy-2-methylpropyl) ketone was
added (3 wt. %, Irgacure 2959, available from Ciba-Geigy, NY).
A polysiloxane additive (0.4 wt. %, DC57, available from Dow
Chemical, Midland, MI) was then added to produce sufficient flow
properties. Finally, the maleimide prepared in Example 1 (25
30 wt. %, MIA250, available from DaiNippon Ink and Chemical
Corporation, Tokyo, Japan) was then added. The curing, solvent
resistance, gloss and surface hardness properties of the coating
described above were then evaluated. The results are shown in
Table 1.

35

Example 6

An aliphatic epoxy acrylate resin (50 wt.%, Laromer 8765,

5 available from BASF, Mt. Olive, NJ) was combined with water (17 wt.%). The maleimide prepared in Example 1 (17 wt. %, MIA250, available from DaiNippon Ink and Chemical Corporation, Tokyo, Japan) was then added along with isopropyl alcohol (15.5 wt. %). A polyether siloxane additive (0.5 wt. %, Glide 440, available
10 from Tego Chemie, VA) was then added to produce sufficient flow properties. The composition was irradiated at three different doses. The curing, solvent resistance, gloss and surface hardness properties of the coating for each dose as described above were then evaluated. The results are shown in Table 1.

15

Example 7

A water dilutable aliphatic urethane acrylic resin (25 wt.%, Ebecryl 2001, available from UCB Radcure, GA) was combined
20 with water (49.5 wt.%). The maleimide prepared in Example 1 (25 wt. %, MIA250, available from DaiNippon Ink and Chemical Corporation, Tokyo, Japan) was added along with a polyether siloxane additive (0.5 wt. %, Glide 440 available from Tego Chemie, VA) to produce sufficient flow properties. The
25 composition was irradiated at two different doses. The curing, solvent resistance, gloss and surface hardness properties of the coating described above were then evaluated. The results are shown in Table 1.

30

Example 8

A highly alkoxyated trimethylolpropane triacrylate resin (61 wt.%, SR 9035, available from Sartomer, PA) was combined with water (24 wt.%). The maleimide prepared in Example 1
35 (14.5 wt. %, MIA250, available from DaiNippon Ink and Chemical Corporation, Tokyo, Japan) was added. A polyether siloxane additive (0.5 wt. %, Glide 440, available from Tego Chemie, VA) was then added to produce sufficient flow properties. The

5 composition was irradiated at two different doses. The curing, solvent resistance, gloss and surface hardness properties of the coating described above were then evaluated. The results are shown in Table 1.

10 Example 9

An aliphatic epoxy acrylate resin (57 wt.%, Laromer 8765, available from BASF, Mt. Olive, NJ) was combined with water (10.5 wt.%). A vinyl ether, hexanedioic acid, bis[4-ethenyloxy)butyl]ester (10.5 wt.%, VEX 4060, available from Allied Signal, NJ) was then added. A maleimide as prepared in Example 1 (21.5 wt. %, MIA250, available from DaiNippon Ink and Chemical Corporation, Tokyo, Japan) was then added along with a polysiloxane additive (0.5 wt. %, DC57, available from Dow Chemical, Midland, MI) to produce sufficient flow properties. . The composition was irradiated at two different doses. The curing, solvent resistance, gloss and surface hardness properties of the coating described above were then evaluated. The results are shown in Table 1.

25

Example 10

(Comparative)

30 A vinyl ether, hexanedioic acid, bis[4-ethenyloxy)butyl]ester (67 wt.%, VEX 4060, available from Allied Signal, NJ) was added to water (22 wt.%). The maleimide prepared in Example 1 (21.5 wt. %, MIA250, available from DaiNippon Ink and Chemical Corporation, Tokyo, Japan) was added along with a
35 polyether siloxane additive (0.5 wt. %, DC57, available from Dow Chemical, Midland, MI) to produce sufficient flow properties. The energy curing properties of the coating could not be evaluated because the water and maleimide were found to be

5 incompatible and no film was formed.

Example 11

10 An aliphatic epoxy acrylate resin (72 wt.%, Laromer 8765,
available from BASF, Mt. Olive, NJ) was combined with water (16
wt.%). The maleimide prepared in Example 2 (11.2 wt. %, MIA-
PE4EO, available from DaiNippon Ink and Chemical Corporation,
Tokyo, Japan) was then added. A polyether siloxane additive
15 (0.8 wt. %, Glide 440, available from Tego Chemie, VA) was then
added to produce sufficient flow properties. The curing,
solvent resistance, gloss and surface hardness properties of the
coating described above were then evaluated. The results are
shown in Table 1.

20

Example 12

(Comparative)

A maleimide prepared in Example 2 (84.5 wt. %, MIA-PE4EO,
available from DaiNippon Ink and Chemical Corporation, Tokyo,
25 Japan) was added to water (15 wt.%). A polyether siloxane
additive (0.5 wt. %, Glide 440, available from Tego Chemie, VA)
was then added to produce sufficient flow properties. The
energy curing properties of the coating could not be evaluated
because the water and maleimide were found to be incompatible
30 and no film was produced.

35

5

Table 1

Example	Cure rate (mJ/cm ²)	Surface Hardness	60° Gloss (%)	Solvent Rubs (MEK)	Solvent Rubs (water)
3	228	Excellent	85-90	65	>200
5	228	Excellent	92	40-44	>200
6	125	Very good	85-88	8	50
6	209	Very good	88-90	12-15	70
6	254	Excellent	88-90	38	>200
7	228	Good	80-82	45	N. A.
7	607	Very Good	80-82	75	N. A.
8	204	Fair	65-70	3	8
8	305	Good	65-70	5	19
9	228	Very Good	86-87	9	31
9	456	Excellent	87-88	31	66
11	228	Fair	86	26	80

The data in Table 1 shows several characteristics of the water compatible energy curable compositions of the present invention. The dose required to cure the composition was similar to that used to cure conventional energy curable materials. The surface hardness and gloss of the cured films were comparable to commercial coatings using photoinitiators. The solvent rubs of the cured compositions were typical of the results that would be achieved with a similar composition containing commercial photoinitiators and resins. This is by exemplified by Example 3 wherein the cure rate does of 228 mJ/cm² represents a conveyor speed of 100 fpm and 200 wpi lamp intensity, represent a commercially practical amount of energy delivered to cure the composition. Examples 3 and 7 depict gloss values greater than 80 which are indicative of a high commercial

5 grade gloss. Example 3 depicts solvent rubs of 65 with MEK and
greater than 200 with water. These values are typically higher
than those shown for conventional commercial coatings cured
under similar conditions. Example 6 shows that by doubling the
10 curing dose, from 125 to 254 mJ/cm², for the energy curable
compositions of the present invention, one can improve its film
properties, such as surface hardness, gloss and crosslink
density as measured by solvent resistance and illustrated by an
increase in MEK solvent rubs from 8 to 38. Example 9 shows a
similar increase in solvent rubs, from 9 to 31 MEK rubs and 31
15 to 66 water rubs. Although a higher cure rate dose was
required, it was still within the range for commercial curing.

The present invention has been described in detail,
including the preferred embodiments thereof. However, it will
20 be appreciated that those skilled in the art may make numerous
variations or modifications of the embodiments that fall within
the scope and spirit of the invention as set forth in the
following claims.

5 What is claimed is:

1. An active water compatible energy curable composition comprising a water compatible compound; a maleimide derivative; and water.

10 2. The energy curable composition of Claim 1 wherein said water compatible compound is selected from the group consisting of acrylate resins; methacrylate resins; acrylic dispersions; urethane resins; vinyl alcohols such as ethylene vinyl alcohol and ethylene vinyl alcohol; vinyl alcohol
15 copolymers such as ethylene vinyl alcohol copolymer; polysaccharides; polysucrose; and glucose.

3. The energy curable composition of Claim 1 further comprising a compound copolymerizable with the said maleimide derivative and water compatible compound.

20 4. The energy curable composition of Claim 3 wherein said copolymerizable compound comprises at least one compound selected from the group consisting of a compound having at least one group selected from an acryloyloxy group and methacryloyloxy group, and a compound having vinyl ether group.

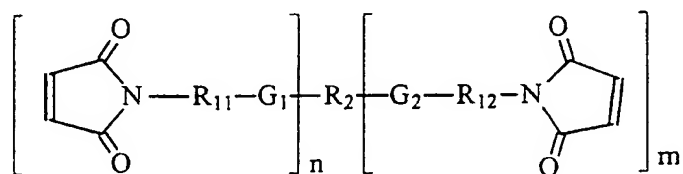
25 5. The energy curable composition of Claim 4 wherein said compound having at least one group selected from an acryloyloxy group and methacryloyloxy group comprises at least one compound selected from (poly)ester (meth)acrylate, urethane (meth)acrylate, epoxy (meth)acrylate, (poly)ether
30 (meth)acrylate, at least one compound selected from the group consisting of an alkyl (meth) acrylate, an alkylene (meth)acrylate, a (meth)acrylate having aromatic group, and a (meth)acrylate having alicyclic group.

35 6. The energy curable composition of Claim 5 wherein said compound having vinyl ether group comprises at least one compound selected from the group consisting of an alkyl vinyl ether having a terminal group substituted with at least one selected from the group consisting of a hydrogen atom, a halogen

5 atom, a hydroxyl group, and an amino group, a cycloalkyl vinyl ether having a terminal group substituted with at least one selected from the group consisting of a hydrogen atom, a halogen atom, a hydroxyl group, and an amino group, and at least one vinyl ether selected from the group consisting of a monovinyl
 10 ether, a divinyl ether, and a polyvinyl ether in which a vinyl ether group is connected with alkylene group; and in which a vinyl ether group is connected with at least one group with and without substituent selected from the group consisting of alkyl group, cycloalkyl group, and aromatic group, via at least one
 15 linkage selected from the group consisting of an ether linkage, an urethane linkage, and an ester linkage.

7. An active water compatible energy curable composition comprising a water compatible compound; water; and a maleimide derivative of the formula:

20



wherein n and m each independently represent an integer of 1 to 5, and the total of m and n is 6 or smaller;

R₁₁ and R₁₂ each independently represent a linking group selected from the group consisting of an alkylene group, an
 25 alicyclic group, an arylalkylene group, and a cycloalkylalkylene group;

G₁ and G₂ each represent an ester linkage selected from the group consisting of -COO- and -OCO-;

and R₂ represents a linking chain having an average
 30 molecular weight of 100 to 100,000 selected from the group consisting of a (poly)ether or (poly)ester linking chain, in which at least one organic group consists of a group or groups

5 selected from a straight or branched chain alkylene group, an alkylene group having a hydroxyl group, an alicyclic group, an aryl group, an arylalkylene group, and a cycloalkylalkylene group connected via at least one linkage selected from the group consisting of an ether or ester linkage.

10 8. The energy curable composition of Claim 7 wherein R_2 is a (poly)ether linking chain having an average molecular weight of 100 to 100,000, and comprised of repeating units containing at least one group selected from a C_2 - C_{24} straight or branched chain alkylene group, a C_2 - C_{24} alkylene group having a
15 hydroxyl group, and a C_6 - C_{24} aryl group.

9. The energy curable composition of Claim 8 wherein R_2 is comprised of repeating units containing at least one group selected from a C_2 - C_{24} straight or branched chain alkylene group or a C_2 - C_{24} alkylene group having a hydroxyl group.

20 10. The energy curable composition of Claim 7 wherein R_2 is a (poly)ester linking chain having an average molecular weight of 100 to 100,000, and comprised of repeating units containing at least one group selected from a C_2 - C_{24} straight or branched chain alkylene group, a C_2 - C_{24} alkylene group having a
25 hydroxyl group, and C_6 - C_{24} aryl group.

11. The energy curable composition of Claim 9 wherein R_2 is comprised of repeating units containing at least one group selected from a C_2 - C_{24} straight or branched chain alkylene group or a C_2 - C_{24} alkylene group having a hydroxyl group.

30 12. The energy curable composition of Claim 7 wherein said water compatible compound is selected from the group consisting of acrylate resins; methacrylate resins; acrylic dispersions; urethane resins; vinyl alcohols such as ethylene vinyl alcohol and ethylene vinyl alcohol; vinyl alcohol
35 copolymers such as ethylene vinyl alcohol copolymer; polysaccharides; polysucrose; and glucose.

13. The energy curable composition of Claim 7 wherein said water compatible compound is a resin selected from the

5 group consisting of acrylate and urethane resins.

14. The energy curable composition of Claim 13 wherein said acrylate resin is aliphatic epoxy acrylate.

15. The energy curable composition of Claim 13 wherein said resin uerthane resin is aliphatic urethane acrylate.

10 16. The energy curable composition of Claim 7 further comprising a compound copolymerizable with the said maleimide derivative and water compatible compound.

17. The energy curable composition of Claim 16 wherein said copolymerizable compound comprises at least one compound
15 selected from the group consisting of a compound having at least one group selected from an acryloyloxy group and methacryloyloxy group, and a compound having vinyl ether group.

18. The energy curable composition of Claim 17 wherein said compound having at least one group selected from an
20 acryloyloxy group and methacryloyloxy group comprises at least one compound selected from (poly)ester (meth)acrylate, urethane (meth)acrylate, epoxy (meth)acrylate, (poly)ether (meth)acrylate, at least one compound selected from the group consisting of an alkyl (meth) acrylate, an alkylene
25 (meth)acrylate, a (meth)acrylate having aromatic group, and a (meth)acrylate having alicyclic group.

19. The energy curable composition of Claim 17 wherein said compound having vinyl ether group comprises at least one compound selected from the group consisting of an alkyl vinyl
30 ether having a terminal group substituted with at least one selected from the group consisting of a hydrogen atom, a halogen atom, a hydroxyl group, and an amino group, a cycloalkyl vinyl ether having a terminal group substituted with at least one selected from the group consisting of a hydrogen atom, a halogen
35 atom, a hydroxyl group, and an amino group, and at least one vinyl ether selected from the group consisting of a monovinyl ether, a divinyl ether, and a polyvinyl ether in which a vinyl ether group is connected with alkylene group; and in which a

5 vinyl ether group is connected with at least one group with and without substituent selected from the group consisting of alkyl group, cycloalkyl group, and aromatic group, via at least one linkage selected from the group consisting of an ether linkage, an urethane linkage, and an ester linkage.

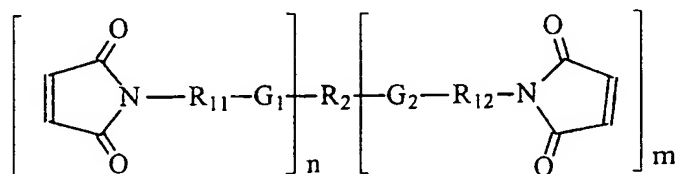
10 20. A printing ink or coating comprising the active water compatible energy curable composition of Claim 1

21. A printing ink or coating comprising the active water compatible energy curable composition of Claim 7.

15 22. A method for curing an active water compatible energy curable composition which comprises: irradiating an active energy curable composition consisting of a water compatible compound, water and a maleimide derivative.

23. The method according to Claim 22 wherein said maleimide derivative is of the formula:

20



wherein n and m each independently represent an integer of 1 to 5, and the total of m and n is 6 or smaller;

R₁₁ and R₁₂ each independently represent a linking group selected from the group consisting of an alkylene group, an alicyclic group, an arylalkylene group, and a cycloalkylalkylene group;

25 G₁ and G₂ each represent an ester linkage selected from the group consisting of -COO- and -OCO-;

and R₂ represents a linking chain having an average molecular weight of 100 to 100,000 selected from the group consisting of a (poly)ether or (poly)ester linking chain, in
30 which at least one organic group selected from straight or

5 branched chain alkylene group, straight or branched chain
alkylene group having a hydroxyl group, alicyclic group, aryl
group, arylalkylene group, and a cycloalkylalkylene group
connected via at least one linkage selected from the group
consisting of an ether or ester linkage.

10 24. The method according to Claim 23 wherein said water
compatible compound is selected from the group consisting of
acrylate resins; methacrylate resins; acrylic dispersions;
urethane resins; vinyl alcohols such as ethylene vinyl alcohol
and ethylene vinyl alcohol; vinyl alcohol copolymers such as
15 ethylene vinyl alcohol copolymer; polysaccharides; polysucrose;
and glucose.

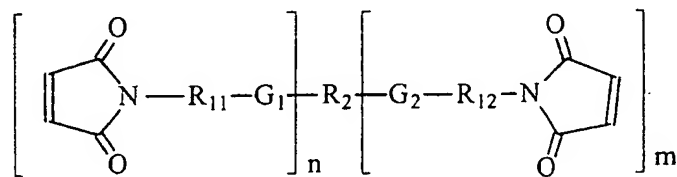
25. The method according to Claim 22 wherein the need to
dry the energy curable composition prior to irradiation is
eliminated.

20 26. The method according to Claim 22 wherein the need to
dry the energy curable composition after irradiation is
eliminated.

27. The method according to Claim 23 wherein R_2 of the
maleimide derivative is a (poly)ether or (poly)ester linking
25 chain, having a molecular weight of greater than 200.

28. The method according to Claim 24 further comprising
adding a compound copolymerizable with the said maleimide
derivative and water compatible compound.

29. An active energy curable composition comprising a
30 maleimide derivative of the formula:



wherein n and m each independently represent an integer of

5 1 to 5, and the total of m and n is 6 or smaller;

R_{11} and R_{12} each independently represent a linking group selected from the group consisting of an alkylene group, an alicyclic group, an arylalkylene group, and a cycloalkylalkylene group;

10 G_1 and G_2 each represent an ester linkage selected from the group consisting of -COO- and -OCO-; and

R_2 is selected from the group consisting of a (poly)ether or (poly)ester linking chain, in which at least one organic group selected from straight or branched chain alkylene group, 15 straight or branched chain alkylene group having a hydroxyl group, alicyclic group, aryl group, arylalkylene group, and a cycloalkylalkylene group connected via at least one linkage selected from the group consisting of an ether or ester linkage, having a molecular weight of greater than 200.

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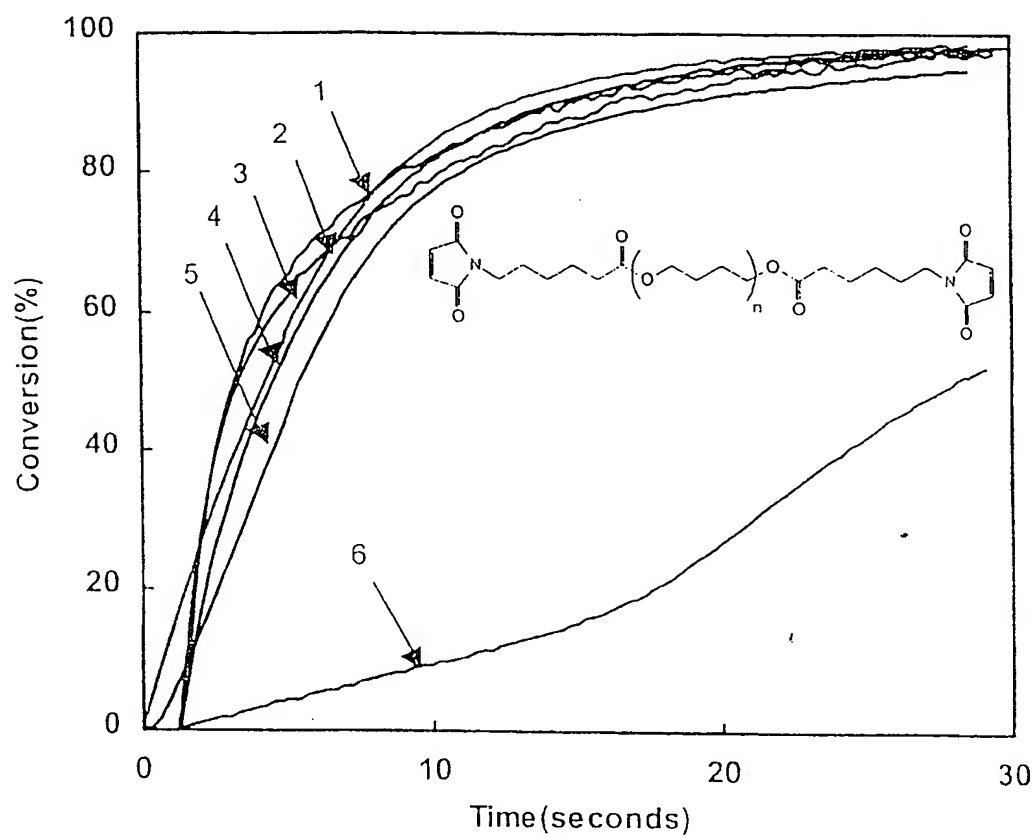


Figure 1

2/2

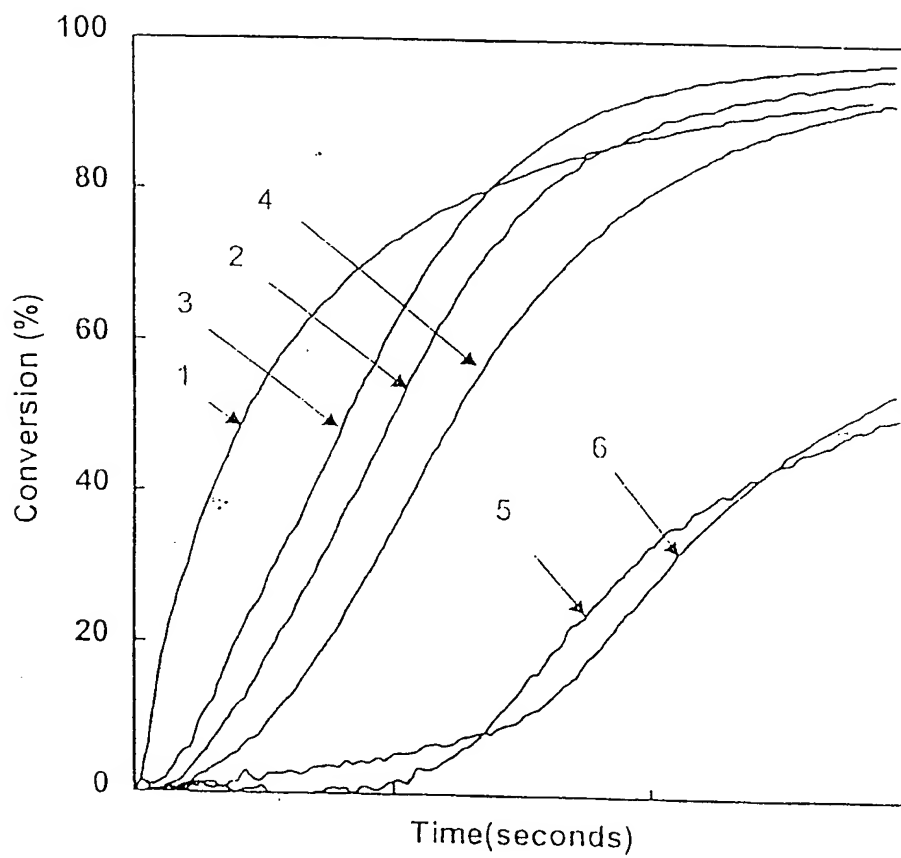
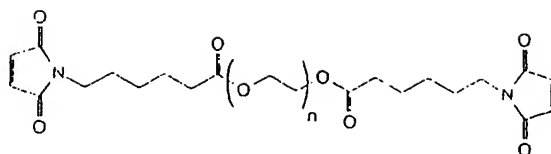


Figure 2

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/24300

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C08F2/48 C08F22/40 C08L67/00 C08L71/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C08F C08L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 066 523 A (MCGINNISS VINCENT D) 3 January 1978 (1978-01-03) claims ---	1-3
X	US 5 034 279 A (WILSON JR THOMAS H ET AL) 23 July 1991 (1991-07-23) claims ---	1
X	WO 98 07759 A (JOENSSON E SONNY ;HOYLE CHARLES E (US); CLARK SHAN CHRISTOPHER (US) 26 February 1998 (1998-02-26) cited in the application the whole document --- -/--	29

☒ Further documents are listed in the continuation of box C

☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Z" document member of the same patent family

Date of the actual completion of the international search

20 July 1999

Date of mailing of the international search report

28/07/1999

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/24300

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CHARLES E. HOYLE ET AL.: "Photoinitiator free polymerization of maleimides and vinyl ethers" ACS SYMPOSIUM SERIES, vol. 673, 1997, pages 133-149, XP002077177 page 137 ----	7-28
A	S. C. CLARK ET AL.: "Photoinitiated polymerization of acrylates using functional maleimides" POLYMER PREPRINTS, vol. 37, no. 2, 1996, pages 348-349, XP002077361 cited in the application page 348 ----	7-28
A	US 4 079 041 A (BAUMANN NIKLAUS ET AL) 14 March 1978 (1978-03-14) cited in the application column 1, line 56 - column 2, line 45 column 6, line 8 - column 8, line 14 ----	7-28
A	US 3 920 618 A (ICHIMURA KUNIHIRO ET AL) 18 November 1975 (1975-11-18) cited in the application ----	7-28
A	EP 0 618 237 A (FUSION SYSTEMS CORP) 5 October 1994 (1994-10-05) cited in the application the whole document & US 5 446 073 A ----	7-28
A	US 3 729 446 A (HOLUB F ET AL) 24 April 1973 (1973-04-24) ----	7
A	US 4 675 414 A (DEFUSCO ALBERT A ET AL) 23 June 1987 (1987-06-23) -----	7

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/24300

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4066523 A	03-01-1978	US 4025409 A	24-05-1977
		US 4035272 A	12-07-1977
		US 4094843 A	13-06-1978
US 5034279 A	23-07-1991	US 4904360 A	27-02-1990
		CA 1300308 A	05-05-1992
		EP 0260010 A	16-03-1988
		JP 63170471 A	14-07-1990
WO 9807759 A	26-02-1998	AU 4085797 A	06-03-1998
US 4079041 A	14-03-1978	CH 601384 A	14-07-1978
		CA 1098245 A	24-03-1981
		DE 2626769 A	13-01-1977
		DE 2661043 C	31-08-1989
		FR 2316257 A	28-01-1977
		GB 1544299 A	19-04-1979
		JP 1322498 C	11-06-1986
		JP 52000988 A	06-01-1977
		JP 60037123 B	24-08-1985
		US 4163097 A	31-07-1979
		US 4158731 A	19-06-1979
		US 4158730 A	19-06-1979
US 3920618 A	18-11-1975	JP 49090385 A	29-08-1974
		JP 834645 C	18-11-1976
		JP 49058196 A	05-06-1974
		JP 51013199 B	26-04-1976
		JP 822525 C	28-07-1976
		JP 49058186 A	05-06-1974
		JP 50038156 B	08-12-1975
		DE 2349948 A	02-05-1974
EP 0618237 A	05-10-1994	US 5446073 A	29-08-1995
		AT 170534 T	15-09-1998
		DE 69412888 D	08-10-1998
		DE 69412888 T	01-04-1999
		ES 2125362 T	01-03-1999
		JP 6298817 A	25-10-1994
US 3729446 A	24-04-1973	NONE	
US 4675414 A	23-06-1987	US 4775729 A	04-10-1988